GINEERING
LIBRARY

JUN 27 1947

# AGRICULTURAL ENGINEERING

JUNE · 1947

The Drifting of Poisonous Dusts Applied by Airplanes — *Dr. F. A. Brooks*

The Use of the Airplane for Agricultural Pest Control — *Orval C. French*

Dry Matter Loss in Haymaking Due to Bacterial Action — *Dr. Harry Miller*

Effects of Soil Erosion on Infiltration and Surface Runoff — *W. D. Ellison*

Air Distribution Through Long Hay in High Narrow Mows — *J. B. Stere, L. S. Singley*

*A.S.A.E. Annual Meeting* • *Philadelphia, Pa., June 22-25*

THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

# A MODERN MIRACLE

## *in Yields per Man-Hour*

From standing crop to bales safely stowed in the barn, this modern method of putting up hay takes only 2.5 man-hours per ton. Under the same typical conditions, handling as loose hay with hayloader, pitchfork and slings would take 3.4 man-hours. Tonnage per man-hour is boosted 36 percent, yet this is only the minor gain from the Case system of haymaking.

Less exposure to sun saves more of carotene, the critical pro-vitamin A. Less exposure to dew and less risk of rain guard the precious protein, soluble carbohydrates and minerals from leaching. Loss of leaves by shattering, from over-curing and repeated handling, is minimized.

Bright green in color, tempting in aroma, such hay earns the name "Packaged Pasture." In extra protein alone it often carries a per-acre premium equal to several bags of bran. In flow of milk and growth of young animals it multiplies still further the yield from man-hours in the meadow.

Designed and priced for profitable ownership by individual farmers, the Case Sliced-Hay baler is so simple that boys can operate it. Like all Case machines it is built for ENDURANCE, the quality that holds down equipment charges per year and per acre.

Case engineering carries things through, along these parallel paths, to the end-result. That final purpose is to achieve the highest net yield per man-hour, after all deductions for other costs, especially the over-all costs for power and machinery. Thus comes better nourishment for the nation, better income for the farm family, less of drudgery and more of dignity in farm work.

**CASE** ☆ ☆

EDUCATIONAL MATERIAL ON ADVANCED PRACTICES. In cooperation with the Soil Conservation Service and other agricultural authorities Case has prepared movies, booklets, etc., of educational value. Most of the films are in full color and sound; all are in 16 mm. width. Several have parallel booklets of similar scope. Charts and posters are suited to classroom and exhibit use. Some of the subjects are terracing with plows, building ponds, making high-protein hay. Send for booklet, "Visual Education Materials." J. I. Case Co., Racine, Wis.

# Plywood does another Farmhouse Remodeling Job!

One before and two after photographs of exterior rural home of Lt. Col. and Mrs. R. D. Stevens, Fayetteville, Arkansas. Remodeling design by Architect Keith Hinchcliff.

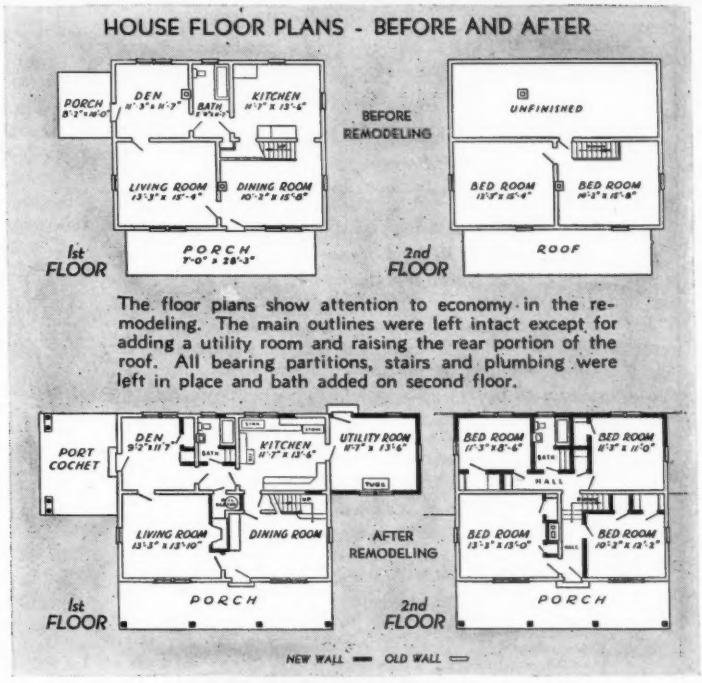
House floor plans before and after—The plans show economy in remodeling. Main outlines were left intact except for adding a utility room and raising the rear of roof. Bearing partitions, stairs and plumbing were left in place.

**DOUGLAS FIR PLYWOOD** is frequently used for the hardest jobs in house remodeling—the places which are most critical and which receive the greatest wear and stress in service.

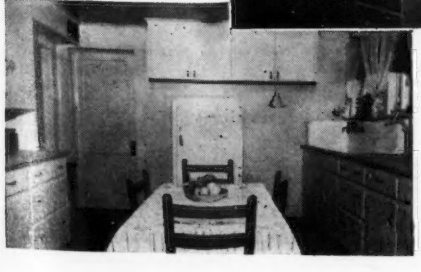
The rural home remodeling illustrated on this page is an example.

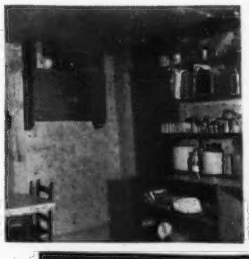
Here fir plywood was used as an underlay over rough, worn floors. Linoleum cemented over it will remain smooth, and give added years of service. Walls and ceilings of the kitchen, utility room and bath were fir plywood with paint or stain finishes. Such walls take the wear imposed by daily use, remain clean and are easily refinished.

For cabinet work in the kitchen, utility room, bath, linen closets, and numerous built-in fixtures and equipment in the modern house, plywood has no substitute. The wide, easily-worked panels are available in a range of thicknesses to suit the job. There is wide latitude in finishing with stains, paints, varnishes, enamels, and wallpaper.



Plywood was used for linoleum underlay, walls, ceilings and cabinets in kitchen.





Another view of kitchen. One coat of flat white paint and one coat of flat white enamel was used to finish the plywood.

DOUGLAS FIR PLYWOOD
LARGE, LIGHT, STRONG
Real Wood PANELS

**Douglas Fir Plywood Association Tacoma 2, Wash.**

# AGRICULTURAL ENGINEERING

*Established 1920*

## CONTENTS FOR JUNE, 1947

*Vol. 28, No. 6*

EDITORIAL ..... 231

THE DRIFTING OF POISONOUS DUSTS APPLIED BY AIRPLANES AND LAND RIGS ..... 233
*By F. A. Brooks*

USE OF THE AIRPLANE FOR PEST CONTROL ..... 240
*By O. C. French*

DRY MATTER LOSS IN HAYMAKING DUE TO BACTERIAL ACTION ..... 243
*By Harry Miller*

SOIL EROSION STUDIES — PART III ..... 245
*By W. D. Ellison*

FARM WORK SIMPLIFICATION — A JOINT PROBLEM FOR MANAGEMENT, ENGINEERING, AND COMMODITY SPECIALISTS ..... 249
*By Paul R. Hoff and Ivan R. Bierly*

THE USE OF HEATED AIR FOR HAY CURING ..... 251
*By H. D. Bruhn*

AIR DISTRIBUTION THROUGH LONG, LOOSE HAY IN HIGH NARROW MOWS ..... 254
*By J. B. Stere and L. S. Singley*

CURING BALED HAY ..... 257
*By C. K. Shedd and E. L. Barger*

AIR FLOW THROUGH BALED HAY ..... 259
*By A. T. Hendrix*

RESEARCH NOTES ..... 261

NEWS SECTION ..... 262

PERSONNEL SERVICE BULLETIN ..... 272

This Journal is owned, edited, and published monthly by the American Society of Agricultural Engineers.

Editorial and advertising departments at the executive office of the Society, Saint Joseph, Michigan. Publication office at Benton Harbor, Michigan.

OFFICERS AND COUNCIL
OF THE A.S.A.E.

MARK L. NICHOLS . . . *President*
J. D. LONG . . . *Past-President*
R. H. DRIFTMIER . . *Past-President*
C. N. HINKLE . . . . *Councilor*
P. T. MONTFORT . . . *Councilor*
W. J. COULTAS . . . *Councilor*
HENRY GIESE . . . . *Councilor*
F. E. PRICE . . . . . *Councilor*
D. A. MILLIGAN . . . *Councilor*

RAYMOND OLNEY, *Secretary-Treasurer*
RALPH A. PALMER, *Assistant Secretary*

SUBSCRIPTION PRICE: $3.00 a year, plus an extra postage charge to all countries to which the second-class postage rate does not apply; to A.S.A.E. members anywhere, $2.00 a year. Single copies (current), 30 cents each.

POST OFFICE ENTRY: Entered as second class matter, October 28, 1933, at the post office at Benton Harbor, Michigan, under the Act of August 24, 1912. Additional entry at St. Joseph, Michigan. Acceptance for mailing at the special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 11, 1921.

The American Society of Agricultural Engineers is not responsible for statements and opinions advanced in its meetings or printed in its publications; they represent the views of the individuals to whom they are credited and are not binding on the society as a whole.

TITLE: The title AGRICULTURAL ENGINEERING is registered in the United States Patent Office.

COPYRIGHT: Copyright, 1947, by the American Society of Agricultural Engineers.

AGRICULTURAL ENGINEERING is a member of the Audit Bureau of Circulations.

Reprints may be made from this publication on condition that full credit be given AGRICULTURAL ENGINEERING and the author, and that date of publication be stated.

ADVERTISING REPRESENTATIVES

Chicago, 2: DWIGHT H. EARLY
100 North LaSalle St.
Telephone: CENtral 2181

New York, 17: A. M. WILLCOX
420 Lexington Ave.
Tele: LEXington 2-4732

RAYMOND OLNEY
*Editor and Business Manager*

# EDITORIAL

## Opportunities in Farm Safety Week

WHILE agricultural engineers should be, and many are, safety-minded the year round, National Farm Safety Week next month (July 20-26) provides a particularly good opportunity to sell safety.

A lot of help is available from the radio, press, farm organizations, dealers, and other agencies. The audience is made receptive by repeated reminders from many directions.

It is a time to let people know that agricultural engineers are interested in farm safety the year round; that a lot of engineering is involved; that properly designed farm structures and equipment, correctly used, can increase farm safety, satisfaction, and net income. Now is the time to plan to make the most of this opportunity.

There are a lot of things farmers need to hear or hear again, directly or indirectly from agricultural engineers in farm power and machinery work, about safety with the overage equipment still in service, the new types of equipment becoming available, the old familiar man-killers such as the unguarded power take-off, and the particular types of equipment they will be using in July and August.

Many agricultural engineers in rural electrification work are in particularly close and effective contact with farmers, and can use this opportunity to encourage safe wiring, equipment, and methods in use of electricity, together with improved use of lights to minimize other hazards.

For farm structures men it will be an opportune time to emphasize safe design in new construction; maintenance, repair, and housekeeping; safe storage practices; and fire safety as well as elimination of direct accident hazards.

Soil and water specialists will have a narrower range of safety matters to emphasize, and can concentrate on safety aspects of farm ponds, flood protection, gullies and ditches, and work methods in operations for soil and water conservation, drainage, irrigation, land clearing, and similar activities.

Development and conservation of human values is the ultimate objective of agricultural engineering. Farm safety work is one of the most direct approaches to the conservation of human values. And National Farm Safety Week is the most effective time for influencing farmers to practice farm safety. It will be to the credit and interest of agricultural engineers, individually and collectively, to identify themselves with and take a more active part than ever before, in National Farm Safety Week this year.

## Wanted: A Force Feeder for Corn

A GOOD sound Iowa corn and livestock farmer, and research man in the packing industry, recently gave us an idea of a type of fertilizer distributor he wants and has not been able to locate.

He has what many farmers might consider some fair to middling corn land, but he wants to pump fertilizer into it as if he had to grow corn on barren sand. For his money the fertilizer attachment on his planter isn't enough. It won't put enough fertilizer where he wants it to force-feed the spreading roots of the sprouted seedlings. He wants to put in $35 to $40 worth of fertilizer per 100-bu yield-capacity in hybrid seed, and he wants it 5 to 6 in deep and 6 to 8 in from the plant.

He says he has done it and that it pays, even with equipment poorly adapted to the job. He wants equipment that will combine the operation with his first and second cultivations, put the fertilizer down where he thinks it will do the most good and have hoppers big enough to minimize delays for refilling.

Maybe this is one of those individual demands which will never support quantity production, or possibly it is a straw in the wind. This man is one of those leading farmers whose novel individual practices at any one time have a way of becoming common practice several years later.

The same principle and equipment would be applicable to some extent even in the event of an unfavorable change in the price relationship between corn and fertilizer.

Possibly this requirement could be met by some comparatively simple adaptation of equipment already in quantity production. If not, possibly results will create the demand to justify production of a new machine. If some manufacturer is already working in this direction, here is a likely cooperator for field tests (name on request).

At any rate we would be interested in hearing from engineers on fertilizer placement research, as to how this farmer's practice checks with the indications from some of their experiments.

## Agricultural Engineering in Comparison

SOME interesting indications as to how agricultural engineers rank in the whole field of engineering are reflected in the "Distribution of Roster Registrants" recently published by the National Roster of Scientific and Specialized Personnel, U. S. Department of Labor.

In considering these figures, it must be borne in mind that the 806 agricultural engineers recorded represent only about one-third of the field, as indicated by membership in the American Society of Agricultural Engineers. In contrast, the number of engineers reported in some of the other engineering fields exceed considerably the membership of the societies representing those fields.

This may indicate a low degree of interest on the part of agricultural engineers in being included on the Roster. Or it may indicate that the membership of the A.S.A.E. is more fully representative of the personnel in its field than are those of some of the other engineering societies. Probably both of these conditions are true to some extent.

The 806 agricultural engineers included are slightly less than 0.4 per cent of the 202,554 engineers on the Roster as of December 31, 1946. Women registrants were a small proportion of the total engineers and none were indicated among the agricultural engineers, although some might have reported if they so desired.

In median age, the agricultural engineers, at 38.8 years, were slightly lower than the 39.9 years of the whole engineering group. This reflects the comparative youth of our field, and its growth in recent years by graduation of men from professional curriculums in agricultural engineering. Still, two other new fields of engineering had notably lower median ages, between 31 and 32.

In education the agricultural engineers showed a slightly lower percentage of doctor's degrees than the total engineering group, 1 per cent, against 1.18+ per cent. In master's degrees, on the other hand, 16+ per cent of the agricultural engineers were represented, against only 7.3+ per cent of all engineers. This apparently is a reflection of the closer association of the agricultural engineers with biological and agricultural scientists, whose progress is more often measured in degrees. It also suggests that in a few years our representation in doctor's degrees may be considerably higher than at present. *(Continued on page 260)*

# Here's How ORCO

## "SURROUNDS" PROBLEMS IN RUBBER

1 ORCO keeps abreast of constant changes in the crude rubber situation

2 ORCO conducts continuous study of all types of synthetic rubbers

3 ORCO develops the best compounding ingredients for each type of synthetic

4 ORCO co-operates with leading technical societies in development work

5 ORCO utilizes latest testing methods and laboratory equipment

6 ORCO maintains specialized engineering service on mold designing

7 ORCO maintains engineering staff specializing on tools and equipment

8 ORCO factory facilities are organized and equipped for large or small volume requirements

**We invite your inquiries on specific problems**

The Ohio Rubber Company

Orco-operation

Willoughby Ohio

Factories: WILLOUGHBY, OHIO • LONG BEACH, CAL. • CONNEAUTVILLE, PA.

Branch Offices: DETROIT · NEW YORK · CHICAGO · INDIANAPOLIS · CLEVELAND · BOSTON

AGRICULTURAL ENGINEERING

VOL. 28 JUNE, 1947 No. 6

# The Drifting of Poisonous Dusts Applied by Airplanes and Land Rigs

By F. A. Brooks

FELLOW A.S.A.E.

FOR many years the necessary practice of dusting tomato vines with calcium arsenate, applying 30 lb per acre for control of the tomato worm, has caused trouble in adjoining fields where the drift from airplane dusting often deposits 4 lb per acre, and the total off-tract waste of insecticide is generally 50 to 60 per cent. Ordinarily there is a rather rapid "weathering off", but if alfalfa is cut soon after dusting the upwind tomato field, 2 lb of poison with 1½ tons per acre would give a contamination of 650 parts per million, or nearly 100 times the tolerance of 7 parts per million passed by the U. S. Public Health Service.

Last year in Yolo County, Calif., 75 dairy cows were killed and the market for alfalfa hay disrupted because of the drifting of arsenic outside tomato fields. Sheep, being less susceptible to arsenicals than cows, were not affected seriously.

Although beekeepers had been complaining for many years[1]* over the annual loss of hundreds of colonies, no official restrictions were imposed until the above spectacular losses struck dairymen and hay growers. The local county board of supervisors moved to prohibit dusting by airplane, but the airplane operators brought in evidence that some of the casualties were due to land rigs. A regulatory ordinance[2] was then enacted requiring $5,000 insurance against liability for damage caused by any dusting which is not confined to the field being treated.

*Measured Spread of Dust Applied by Airplane.* An excellent study of airplane dusting is reported by Kruse, Hess and Metcalf[3]. Their dusting operations were carried out during the calm period at early morning, and the flying height was usually 20 to 30 ft. Their extensive investigations included the quantitative determination of distribution of paris green dust laterally from the line of flight as shown in Fig. 1. Their upper curve is of average particle count (ordinate scale to the right). Their lower curve is by weight (ordinate scale to the left). They report that of the total dust discharged "about 20 per cent falls in the central 100 ft of the dusting swath", and altogether "about 28 per cent falls in a swath 200 ft wide. . . . . Thus over 70 per cent of the dust drifts away from the treatment area and for practical purposes may be considered lost." Furthermore, that "this low percentage of recovery is believed due in large part to the fact that commercially available paris greens are of too fine a particle size for most effective distribution by airplane."

*Inherent Difficulties in Confining Dusts Applied by Airplane.* The airplane is inherently bad because it cannot avoid stirring up quiet air. This disturbance is directly proportional to the airplane weight and varies somewhat with engine power. Thus the optimum for minimum dust drift would be a hybrid sailplane Piper Cub whose minimal disturbance would be most quickly quieted by the typical inversion stability of early morning air. This, however, is not the optimum to get dust penetration into foliage (Fig. 2). Secondly, the airplane can dust only a short time in favorable, quiet air because the pilot cannot see well before there is strong daylight and by then it is only about an hour before the beginning of

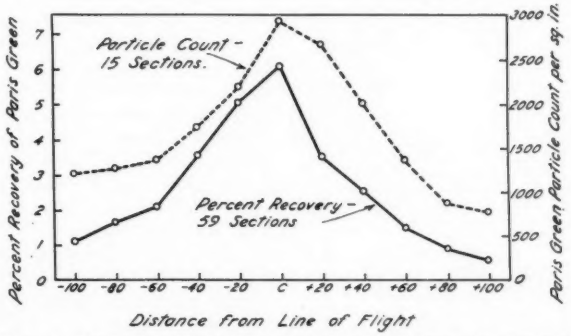

Particle Count - 15 Sections.
Percent Recovery - 59 Sections
Percent Recovery of Paris Green
Paris Green Particle Count per sq. in.
Distance from Line of Flight
0 1 2 3 4 5 6 7
0 500 1000 1500 2000 2500 3000
-100 -80 -60 -40 -20 C +20 +40 +60 +80 +100

Fig. 1 Transverse distribution of paris green dusting by airplane measured by Kruse, Hess, and Metcalf

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at St. Louis, Mo., June, 1946, as a contribution of the Power and Machinery Division.

F. A. BROOKS is agricultural engineer, University of California Agricultural Experiment Station.

EDITOR'S NOTE: In 1943 Dr. Brooks served the Chemical Warfare Service as a consultant in air turbulence, and in 1944 was technician on air turbulence for the U. S. Navy on a smoke project at sea.

* Superscript numbers refer to the appended references.

Fig. 2 *(Left)* Photograph by J. E. Eckert showing airplane at proper height but dust failing to penetrate superstable ground-air layer promptly • Fig. 3 *(Right)* Photograph by J. E. Eckert showing good airplane application of DDT to alfalfa near Blythe, Calif. This created a dense blanket about 15 ft deep, which in 15 min had moved off the field but seemed virtually intact

daytime turbulence. Fig. 3 is a good example of dusting in very quiet air. Third, light fogs, often providing favorable conditions for dust adherence, prevent airplane flying. Fourth, the dust is released considerably above the crop to be treated because of flight obstruction hazards such as border trees, telephone and power lines, and farmstead buildings. Thus the objective, close dusting, is against personal safety. (Fig. 4 in the paper by O. C. French, entitled "The Use of the Airplane for Pest Control", published elsewhere in this issue of AGRICULTURAL ENGINEERING shows good application, except at the field end where the pilot had to clear a border power line.) Finally, accuracy in location of dust application is extremely difficult because of the high speed of the airplane. Usually the dust feed is started too soon. There is always some dribble after shutoff, and sometimes the feed is not shut off completely during the long turning path beyond the end of a run. Some pilots "dump" leftover material simply because their operating system requires the emptying of hoppers before landing. There are, of course, such real advantages in airplane dusting that the practice needs to be modified rather than discontinued.

The helicopter has proved effective in applying dusts to apple trees and hop and grape vines when flying 10 to 15 mph (miles per hour). At this speed (well below the 20 mph when translational lift becomes apparent) the dust is driven downward powerfully and recurves to a height of about 20 ft when the helicopter is at 30 ft. This depth of highly turbulent air exactly fits the hops strung to 20-ft poles, and a large portion of the dust is filtered out by the foliage. Some distance back of the machine, however, the upward and outward dispersion of fine-particle dust can be seen. At 40 mph dusting by helicopter is not considered satisfactory. The translational lift makes the dust dispersion about the same as by fixed-wing airplane.

In general, the special advantage of airplane dusting is its avoidance of going into the field on the ground. Other reasons in favor of airplane dusting are only indirectly related to flying. It is quicker for the grower and high pay per hour to the pilot. Considering respective possibilities for improving the techniques of dusting, it seems that for low crops better application and with less hazard is possible with land rigs. However, the upward spreading of fine dusts (even from land rigs) is seen vividly from an observation airplane.

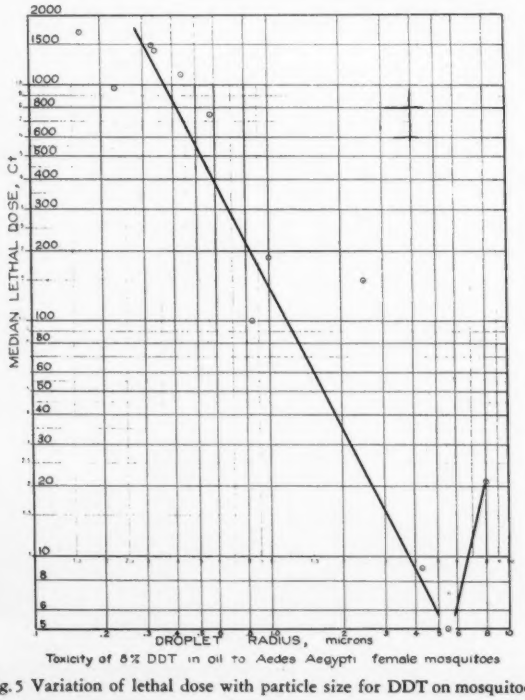



Fig. 5 Variation of lethal dose with particle size for DDT on mosquitoes

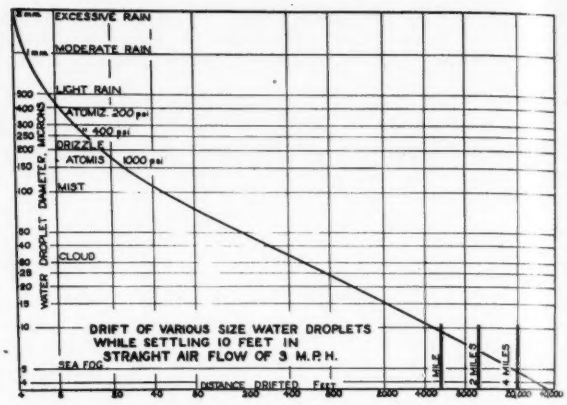



Fig. 4 Graph of particle size vs. distance carried while settling 10 ft in 3 mph straight air flow. Note that drifting several miles is to be expected for particles smaller than 10 microns in diameter. Most insecticide dusts are smaller than this size

*Trend of Development in Land Rig Dusters.* The strongest urge in the development of field dusting machines is to extend the range of their operations into "unfavorable" atmospheric conditions, namely, to make them usable in light daytime winds as well as during early-morning, quiet-air conditions. This calls for in-the-foliage application and, if possible, hoods permitting a traveling, controlled, treatment atmosphere along the same concept as the industrial processing tunnels through which material moves steadily on a conveyor. This is difficult to accomplish in the field because of the bulk of the hood and the need for making sharp U turns at the end of the row, usually just inside a fence.

In developing such a hooded system the perpetual problems of pest control become more specific: (1) Means of creating and spreading the aerosol, (2) adherence and spreading of toxic agent on foliage, (3) avoidance of plant injury, (4) protection of the operator, and (5) mechanical design for minimum cost with seasonal reliability.

The suppliers of toxic materials are making considerable effort toward the means of creating the lethal atmosphere and they offer significant cooperation in the development of new techniques for gas, liquid, or dust. The technical problems of adherence and coverage seem to be the province of state and federal experiment station research. The manufacturers of agricultural equipment, of course, are themselves developing various dusting and spraying machines. Modifications of field apparatus naturally originate mostly with the custom operators or the large farms having their own shops and specialized crews, though again the experiment stations also contribute.

*Particle Size and Rate of Fall.* Underlying all problems of field application of toxic materials is the rate of settling of particles "suspended" in air. Smoke particles and fumes are generally so small that they are subject to Brownian motion. For this class it is more useful to treat their motion relative to air as dispersion of heavy molecules of gas. The usual aerosol particles (large relative to the mean free path length of air molecules) are nevertheless so small that in settling by gravity the air they force aside flows around them in a viscous manner, for which Stokes' Law[4] applies. Accordingly, for small spherical, water droplets in air at 68F the terminal falling velocity is

$$w = 0.00593\, d^2 \mu \text{ ft/min} \qquad [1]$$

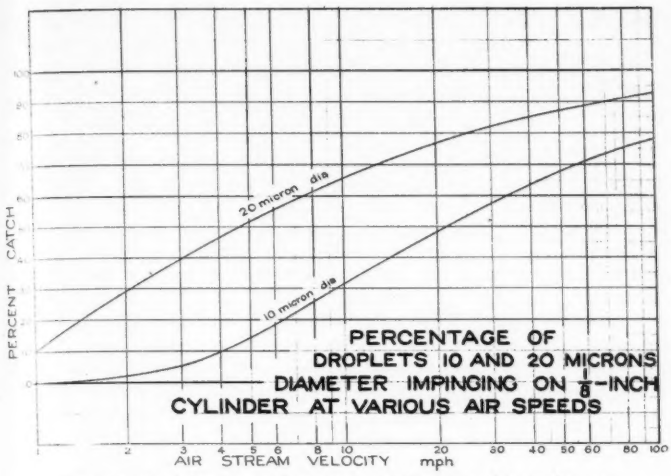

PERCENT CATCH
20 micron dia
10 micron dia
PERCENTAGE OF DROPLETS 10 AND 20 MICRONS DIAMETER IMPINGING ON 1/8-INCH CYLINDER AT VARIOUS AIR SPEEDS
AIR STREAM VELOCITY mph

Fig. 6 Graph of dynamic catch vs. air speed for stems of ⅛-in diameter

where diameter, $d_\mu$, is in microns. The maximum droplet diameter in air for which Stokes' Law is considered to apply is from 80 to 100 microns. Thus the Stokes' Law covers the ranges in particle size normally found for fogs, pollens, spores, and bacteria. Nonspherical shapes usually are handled by corrections to equivalent spherical size for the same falling rate. Corrections are also made in case of excessive mass of suspended matter relative to its supporting air mass.

Mist and rain-size drops from 200 to 6000 microns diameter take an appreciable time to accelerate from rest to terminal velocities and the terminal velocities are determined largely by turbulent-flow resistance. The investigations by Liznar[5] of settling rates of water droplets for this size range have been reworked by Nottage and Boelter[6]. Using their figures and Stokes' Law, Table 1 shows the elapsed times of falling 10 ft from rest in quiet air. The table includes also the horizontal travel to be expected in a straight, 3-mph air drift, which is shown in Fig. 4. It is seen at once that drift control becomes virtually impossible for particles smaller than 10 microns diameter. The dispersion is greater of course in turbulent air.

*Toxicity vs. Fineness of Aerosol Particles.* Lamer[7] and colleagues carefully created fogs of definite size oil droplets containing 8 per cent DDT and measured the lethal properties for Aedes Aegypti mosquitoes. The unit of toxicity is the product of time of exposure (minutes) by aerosol density (micrograms per liter) which causes a 50 per cent kill. Their observations are plotted in Fig. 5 which shows an optimum particle size of about 10 microns diameter. They explain this by Stokes' Law as follows:

> ". . . For a given concentration (C) of aerosol, the time necessary for a critical amount of toxic material to deposit upon a fixed area will therefore vary inversely as the square of the radius . . . namely, that the absolute quantity of toxic material necessary to kill a given insect remains constant regardless of particle size, but the exposure-concentration product, Ct, depends on the rate of fall, and therefore of contact with the insect, in accordance with Stokes' Law. . . . the decreased toxicity as a result of finer subdivision below 5 microns (radius) arises from the fact that 5-micron particles fall (16 cm/min) more rapidly and hence deposit faster upon the insect than do finer particles."

For surface applications of DDT very much larger droplets are desired, because it is only necessary that there be deposits somewhere in the path of an insect, and the larger the deposit the longer it remains lethal. In dry dusting these larger particles are now obtained in makeshift manner by mixing two per cent oil into the "micronized" dust, this quantity being found not to impair the action of the dust-feed mechanism.

In airplane dusting of reservoirs of the Tennessee Valley Authority for control of Anopheles quadrimaculatus mosquito larvae, Metcalf and Hess[8] recommend a particle size for paris green larger than the ordinary commercially available material — "75 per cent (by weight) shall consist of particles 20 microns or greater in diameter." The sample of one supplier showed 78 per cent by weight in particles smaller than 10 microns diameter. Even 25 microns is a microscopic size (0.001 in).

*Catch of Insecticide Dusts by Foliage.* A major fraction of the dusting is intercepted by foliage directly in the aerosol stream before dispersal by eddy-diffusion starts. This initial interception occurs by direct filtering and by momentum as the free air stream is split by the obstruction and flows around on two sides. In the filtering process if surface contact results in adherence, the minimum cleared depth of approaching half-stream is the radius of a particle. There is some superspeed in passing the obstruction so the distance from surface to any given streamline at the position of maximum superspeed is less than in the approaching stream. For the frictionless case the central approach stream is about 50 per cent thicker than the same stream divided on the cylinder diameter. Hence, one can expect direct filtering of axial streams about 1.5 x particle diameters wide. This is a very minor catch. For very small particles subject to Brownian motion, the effective surface stream depth is equal to the length of the mean Brownian path plus particle radius, but the catch then depends on the length of time the particle is within Brownian distance and the probabilities of the motion.

Most important for catching the usual-sized insecticide dusts is the linear momentum of a particle. This tends to impinge the particle on the foliage during the angular acceleration of the air in flowing around such obstruction. The divergent acceleration varies inversely as the size of the obstruction, and inertia is more likely to carry particles through the boundary air onto a small twig surface than onto a large cylinder. This inertia catch is also highly dependent on particle size, the "micronized" particles tending to flow around the obstruction without being caught. The catch by this latter mode of filtering is treated by the Langmuir group[9]. The fol-

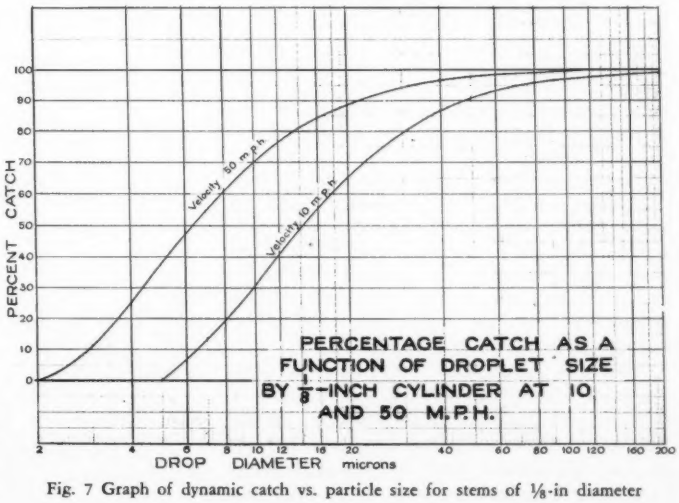

PERCENT CATCH
Velocity 50 m.p.h.
Velocity 10 m.p.h.
PERCENTAGE CATCH AS A FUNCTION OF DROPLET SIZE BY 1/8-INCH CYLINDER AT 10 AND 50 M.P.H.
DROP DIAMETER microns

Fig. 7 Graph of dynamic catch vs. particle size for stems of ⅛-in diameter

lowing examples are evaluated by using the curves they obtained by an automatic differential analyzer.

For a twig having a diameter of ⅛ in (0.01 ft) in a steady wind, the air ribbon ⅛ in thick approaching the twig will divide and flow around. All the particles in the center of the air ribbon would impinge on the twig, but only large particles on the edges of the air ribbon would have enough momentum to travel through the air curving around the twig. There is thus some central thickness of the air ribbon outside which a given size particle will be carried around the twig instead of impinging on it. The ratio of this central cleaned width to the full ⅛-in approaching ribbon is then the "efficiency $E_m$", specified in per cent. This catch varies with free stream velocity as shown in Fig. 6 and also with particle size as shown in Fig. 7. The disadvantage of fine-sized particles is very evident. The catch also varies inversely with the diameter of the obstructing cylinder. Thus a mat of fine glass fibers is ideal for filtering out fine particles.

A catch efficiency of 100 per cent means, however, that air sweeping through foliage would be stripped of all particles only in a cross-sectional area equal to that presented by the foliage. Many particles will thus pass through the foliage uncaught if they are in an air stream not directly approaching an obstruction of the size considered.

*Need for Reconsideration of the Demand for Very Fine-Sized Particles.* In view of the three-fold disadvantages of very fine dusts — poor catch, low lethal power, and long-distance drifting — it seems advisable to investigate the basis of the common axiom: "The finer the particle, the better the control." This might arise from an uncalled-for transfer of laboratory findings to very different field conditions. The literature on toxicity of insecticides is voluminous, but with few direct studies on particle size. It was found desirable to use fine particles for the "sandwich" method[10] to get uniform deposition of dust (by settling in a bell jar), but this requirement is not necessary for field pest control. This technique designed to determine lethal dosage reports 0.000004 mg as sufficient for small worms. A 19-micron diameter water droplet has this weight. There is no mention in this citation of an advantage of very fine particles though they were used in the test.

## EDDY-DIFFUSION OF FINE PARTICLES IN THE ATMOSPHERE

Extensive investigations of the travel of suspended particles in air have been carried out by Bosanquet[11]. This is a close approach to the problem of deposition of drifted insecticides, but the analytical treatment overindicates the spread near the source. Distant from the source the relative fit is good but the mean daytime magnitudes are used for dispersion rates and the 1935 paper does not indicate how to make the necessary changes to suit stratified air turbulence typical for early morning dusting. The dispersion coefficients described in his 1936 paper also do not seem to permit independent modification to suit stable air. Bosanquet's analytical treatment of eddy-diffusion employs the usual exponential solution of the molecular diffusion equation which does not take into account the finite limitations on advection by atmospheric turbulence. Other authors such as Sutton[12] have the same trouble with eddy-diffusion because there is as yet no adequate mathematical solution of turbulence problems.

The more real analytical treatment of eddy-diffusion preferred by the author for the dust drift problem is too complex to present here, but the departures from usual forms can be briefly explained as follows: First, an empirical, finite, mathematical expression is used to specify mean

TABLE I. TERMINAL VELOCITY OF WATER DROPLETS FALLING IN AIR AND TIME FOR FALLING 10 FEET.

| Equiv. Diam. of Particle | Description of Size | Terminal Velocity | Time to Fall 10 ft. from Rest | Distance carried in 3 mph. uniform air |
|---|---|---|---|---|
| microns | | ft./min. | minutes | feet or miles |
| ½ | Brownain max. | 0.0015 | 6750. | 388. miles |
| 1 | | 0.0059 | 1686. | 84. " |
| 2 | | 0.024 | 420. | 21. " |
| 3.5 | | .072 | 139. | 7.0 " |
| 5 | Sea Fog | 0.148 | 67.5 | 3.4 " |
| 10 | | 0.593 | 16.9 | 4,452. feet |
| 20 | | 2.371 | 4.20 | 1,109. " |
| 33 | Cloud | 6.46 | 1.55 | 409. " |
| 50 | | 14.82 | 0.675 | 178. " |
| 80 | | 37.9 | 0.264. | 70. " |
| 100 | Mist | 55.0 | 0.1818 | 48. " |
| 170* | Atomized 1000 lbs/in²* | 120. | .0833 | 22. " |
| 200 | Drizzle | 142. | .0704 | 18.6 " |
| 290* | Atomized 400 lbs/in² " " | 229. | .0437 | 11.5 " |
| 380* | Atomized 200 " " " | 313. | .0320 | 8.4 " |
| 500 | Light Rain | 421. | .0265 | 7.0 " |
| 1 mm | Moderate Rain | 763. | .0179 | 4.7 " |
| 2 " | Excessive Rain | 1041. | .0152 | 4.0 " |
| 3 " | Cloudburst | 1172. | .0145 | 3.8 " |
| 4 " | | 1237. | .0141 | 3.7 " |
| 6 " | Max. drop size | 1307. | .0138 | 3.6 " |
| Free Fall | | 1524. | 0.0131 | 3.5 " |

*French, o.c.; "Spraying Equipment for Pest Control," Univ. of Calif., Agricultural Experiment Station. Bul. 666 - May 1942, Fig. 8, p. 11.

F.A. Brooks 6/46

transverse distribution of concentration, $X$, namely[13],

$$X = X_m [1 - (r/R)^{3/2}]^2, \qquad [2]$$

where $X_m$ is the concentration on the plume axis, $r$ is the radial distance from the plume axis, and $R$ is the mean radial distance to cloud edge. The latter is directly proportional to the standard deviation of the distribution. Secondly, the relation between transverse distribution and gustiness is kept direct, using the standard deviation to express both phenomena. The third major difference from the usual procedure is the inclusion of progressive particle removal from the dust cloud both by settling and by dynamic catch. Fourthly, it is shown that direct account can be taken of the forced dispersion due to the disturbance created by the dusting machine itself. As a fifth difference the author assumes for convenience that

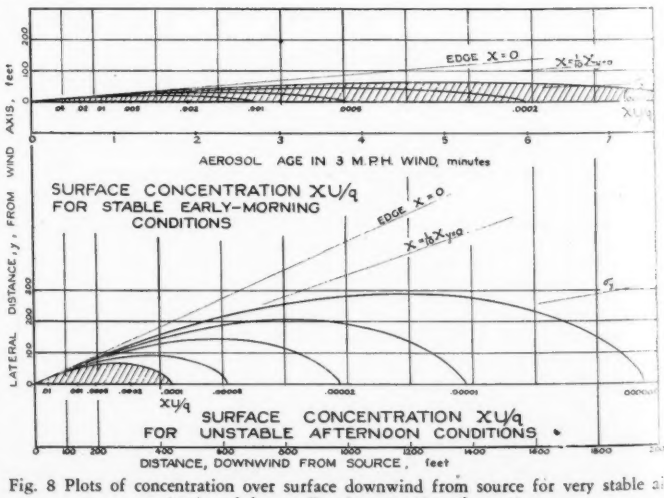



Fig. 8 Plots of concentration over surface downwind from source for very stable air (top) and for small-scale convection (bottom)

there is no vertical gradient in diffusivity or in wind velocity in the given layer.

*Characteristic Degrees of Atmospheric Turbulence Near the Ground.* Attention is directed to the suppression of gustiness to be expected within a layer of stable air and the natural sequence in the morning breakdown of nocturnal stability. Church and Gosline[14] describe the typical morning transition from stable air to convective air under the stable layer. This report taken as an upward supplement to the surface observations of the Latimer group (see Appendix) indicates four distinct degrees of atmospheric turbulence: superbuoyancy stability, normal "stable" air, small-scale convective turbulence, and pillared convection (generating cumulus clouds). Each type seems to differ from the others more than can be properly treated by expressing diffusivity as a function of height. Diffusion in each of the first three types of turbulence can, however, be treated by the same diffusion formula, using only the appropriate magnitudes for gustiness.

The vertical and horizontal gustiness coefficients calculated from the Latimer group observations are $G_z = 0.02$, 0.04, and 0.10; $G_y = 0.03$, 0.054, and 0.16, respectively, for very stable, moderately stable, and small-scale convective conditions.

*Typical Patterns of Concentration and Deposit Rate under a Dust Cloud.* It is not feasible here to develop the analytical expressions for eddy-dispersion, but it is anticipated that these can be published elsewhere. It seems appropriate, however, to show typical distribution for an extreme stability in a strong morning inversion and for noontime small convective conditions. The two distributions shown in Fig. 8 are calculated for a simple fixed source with dispersion only by natural air turbulence. These surface concentrations also represent the rate of particle deposition because deposit rate is the direct production of settling velocity times the surface concentration.

The essential difference in dust deposit from a moving source is that the drift concentration over a given spot decreases as the dust source moves away. For this reason it is most convenient to treat diffusion from moving sources in terms of age since emission. In other words, the dust cloud spreads naturally at a certain rate for given turbulence conditions. Fig. 8 includes the age scale for the basic wind velocity of 3 mph, and it is seen that for the very stable conditions the 1/10 concentration moves outward 17.5 fpm. Thus for a source moving in the direction of the wind with a relative velocity of only 1 mph, the diffusion cone would be telescoped to triple concentrations but which still spread laterally at the rate for fixed source. This produces a dense cloud travelling with the machine, much to the distress of the operator. Going against the wind the diffusion cone is laid as a narrower plume of correspondingly less concentration. The dust plumes from airplanes are laid so fast they seem almost like line sources of short discharge time.

The deposit over a whole field from a moving dust source depends also on its forced turbulence, its travel back and forth, and the carry of the wind. Such a combined effect can be estimated by superposition of the dust deposit patterns along each row travelled.

*Pattern of Dust Deposit at Downwind Fence.* The estimate of dust drifting beyond the downwind fence is related to the total deposit at the fence line which has been calculated for a simple case and is shown in Fig. 9. Again the particle size assumed is 10-micron diameter and the air drift 3 mph in the line of travel of the dusting machine. The rate of dynamic catch is assumed arbitrarily to be the same as the gravity settling rate. An increase in dynamic catch rate by forced turbulence in the foliage would sharpen the peak of Fig. 9. This can be contrasted roughly with the airplane distribution of Fig. 1.

*Field Observations Needed for Empirical Determination of Dust Diffusion System.* A large number of well-located spot measurements of dust deposit can be used to determine the field distribution of any dusting operation, but to get an understanding of the diffusion system it is better to support a few dust-deposit observations with some other kinds of observations, notably of gustiness, mean particle size, aerosol concentrations, and photographs of dust plume.

The plot description should include:

- Name of farm operator
- Name of dusting contractor
- Name of farm owner
- Location of farm
- Location and dimensions of test plot
- Description of surrounding terrain (in respect to turbulence)
- Crop dusted
- Height of foliage, $h$, and its apparent density.

The description of conditions should include:

- Date and time of sunrise
- Starting and ending times (of operation)
- Kind of dust applied
- Rate of discharge
- Speed of machine and its direction
- Length of run and spacing between lines
- Machine-width of dust source and its height above ground
- Dust-particle mean size (settling rate)
- Air-drift velocity and its direction
- Gustiness coefficients
- Dry and wet-bulb temperatures
- Description of air stability (temperature inversion; sky clearness)

Dust samples:

- Four of aerosol concentrations, three of which at downwind fence; one on dust axis, one at near side-fence corner, and one at same distance on other side of first-run axis. Also one far downwind on dust axis (¼ or ½ mile).
- Five of dust deposit, $Q_A$, at the four above locations, and one more at downwind fence at opposite-side corner.

Photographs:

- From overhead, if possible.
- From side showing (a) start of run, (b) near end of run (level flight), and (c) end zoom. These will show first contact distance and vertical diffusion.
- From end of run looking downwind when coincident (vertically) with source. This is to show angle of horizontal spread in lieu of photograph from directly overhead.

Entomological observations as needed by collaborators.

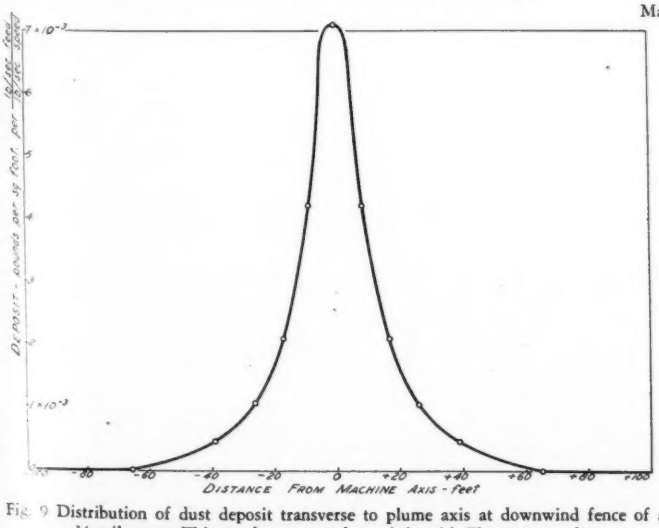



Fig. 9 Distribution of dust deposit transverse to plume axis at downwind fence of a ¼-mile row. This can be compared roughly with Fig. 1 to see the advantage of in-the-foliage application

## CONCLUSIONS

The present conclusions from this study are as follows:

1 The use of very fine particles is a mistake.

2 Outside field contamination by airplane dusting cannot be prevented, unless large-size particles are used and sharp cutoffs developed.

3 Dusting machines would be most efficient if designed to get high dynamic catch within the foliage with minimum upward dispersion.

4 Outside contamination concentration might be decreased by creating artificial air turbulence at the downwind edges of the treated field.

## REFERENCES


1 Eckert, J. E., Allinger, H. W.: Relation of Airplane Dusting to Beekeeping. Journal of Economic Entomology, vol. 29 (5), pp. 885-895, November 4, 1936.

2 Cummins, T. D., chairman, Yolo County Board of Supervisors: Ordnance No. 201, Feb. 8, 1946. First half of section 3: "Before any permit is issued to any applicant hereunder, the applicant shall deliver to the agricultural commissioner a certificate of insurance or other evidence satisfactory to said agricultural commissioner that applicant is insured by an insurance company in not less than the sum of $5,000 against liability for damage caused by applicant or any person hired or engaged by applicant as an independent contractor or otherwise using, spreading, spraying, dusting, or applying any poisonous dry material or materials or mixture of poisonous dry materials or causing such materials to settle or deposit upon any land or property of another person." (Note that a year later dairymen seek changes to strengthen possibility of getting convictions and to outlaw calcium arsenate altogether.)

3 Kruse, C. W., Hess, A. D., and Metcalf, R. L.: Airplane Dusting for Control of Anopheles Quadmaculatus on Impounded Waters, Jour. National Malaria Soc., vol. 3 (3), Sept., 1944, pp. 197-209, specifically pp. 209 and 206.

4 Prandtl-Tietjens: Applied Hydro- and Aero-Mechanics. McGraw-Hill Book Co., New York, 1934, p. 113. (Note that this viscosity has dimensions dyne sec/sq cm.)

5 Liznar, J.: Meteorol. Zeitschr., 31,339 (1914).

6 Nottage, H. B. and Boelter, L. M. K.: Dynamic and Thermal Behavior of Water Drops in Evaporative Cooling Processes. A. S. H. & V. E. Trans., vol. 46, 1942, table 8—or in Heating, Piping and Air Conditioning, vol. 12 (5): 326-32, May, 1940.

7 Lamer, Hockberg, Hodges, Wilson, and Adamo: Toxicity of DDT to Mosquitoes: Effect of Particle Size on the Efficiency of Oil Aerosols Bearing DDT. O.S.R.D. report No. 4447, Dec. 11, 1944 (N.D.R.C. Div. 10); declassified from "Restricted" to "Open".

8 Metcalf and Hess: The Relation of Particle Size to the Effectiveness of Paris Green Used in Airplane Dusting for Mosquito Control. U. S. Public Health Service, Reports vol. 59, part 2, no. 45, November 10, 1945, pp. 1458-65.

9 Tribus, Myron, and Tessman, J. R., editors: Report on the Development and Application of Heated Wings, Addendum I, Army Air Forces Technical Report No. 4972, Add I., January 9, 1946, unclassified.

10 Campbell, F. L. and Filmer, R. S.: Quantitative Method of Estimating the Relative Toxicity of Stomach-Poison Insecticides. Trans. IV, Int. Cong. Ent., 523, 533, 1929.

11 Bosanquet, C. H.: Eddy-Diffusion of Smoke and Gases in the Atmosphere, App. II of "The Removal of Smoke and Acid Constituents from Flue Gases . . .", by Pearson, Nonhebel, and Ulander: Jour. Inst. of Fuel, vol. 8, no. 39, Feb. 1935, pp. 121-125, 153-155, 196-197. Bosanquet, C. H. and Pearson, J. L.: The Spread of Smoke and Gases from Chimneys. Trans. Faraday Soc., vol. 32 (pt. 8), pp. 1249-1263, 1936.

12 Sutton, O. G.: A Theory of Eddy Diffusion in the Atmosphere. Proc. Royal Soc., Series A, vol. 135, no. 826, Feb. 1, 1932, pp. 143-165.

13 Goldstein, S., editor: Modern Developments in Fluid Dynamics. Clarendon Press, Oxford, 1938, vol. II, fig. 232, p. 584.

14 Church, Phil E. and Gosline, C. A., Jr. Characteristics of Mixing and the Dilution of Waste Stack Gases in the Atmosphere. Annual meeting of the Amer. Meteorological Society, Washington, D. C., May 27, 1946.

15 Scrase, F. J.: Some Characteristics of Eddy Motion in the Atmosphere. (British) Air Ministry, Meteorological Office, Geophysical Memoirs, no. 52, vol. 6, no. 2, H. M. Station—Office, London, W.C.2, 1930.

16 Latimer, Ruben, Pitzer, Gwinn, Norris, and assistants: Correlation of Gas Concentrations with Meteorological Data. O.S.R.D., N.D.-R.C. Div. 10, Nov. 3 and July 14, 1943. Classified "Confidential", but this excerpt released for publication June 14, 1946.


## APPENDIX

### GUSTINESS COEFFICIENCIES DERIVED FROM OBSERVATIONS OF LATIMER AND ASSOCIATES

*Evaluation of Gustiness for Various Air Conditions.* Gustiness can be evaluated directly from hot-wire anemometer records according to the definition

$$G_x = \sqrt{w^2}/U_t = \sigma_x/x \qquad [3]$$

Observations suitable for this interpretation are, however, rather rare. Alternatively, there are considerable gustiness data obtained with bivane meters[15] which can be interpreted according to formula [3]. It is best, of course, that turbulence observations be matched by an observed diffusion rate such as attenuation downwind indicated for continuous line source by the equation

$$G_x = \frac{q/L_y}{1.281\ U\ x\ X_m} \qquad [4]$$

where $q/L_y$ is the source rate; $X_m$, the axial concentration; $U$, the wind velocity, and $x$, the distance from the equivalent line source.

Specific information for this with stable air under strong inversion conditions near Davis, Calif., was gathered by Ruben, Pitzer[16] and colleagues in a study for the Chemical Warfare Service and is presented in Table 2. The pertinent part of their report is as follows:

"The experimental field was a grazing field in the Yolo Bypass. The field was very flat and had a slope of not more than 6 ft per mile. There were no trees or other obstructions within several miles of the experimental plot. The nearest hills of any size were about 30 miles away. The ground cover was grass about two feet long, which was bent over forming a fairly smooth surface. This region, except on very rare occasions, was free from katabatic winds.

"Butane was emitted (as a liquid) from a ½-in pipe line 50 yd long, with orifices (No. 70 drill, about every yard) directed slightly upward making a vapor cloud about 24 in high in 36 in distance. Wind velocities and profiles were measured with four sensitive three-cup anemometers placed at ½, 1, 2, and 4 meters (above ground). Temperature gradients were measured between 0.1 and 1.0 meters, 1 and 2 meters, 2 and 3½ meters, and 3½ and 6 meters, and they were recorded continuously on two Leeds and Northrup micromax recorders.

"Gustiness was measured by the British type bidirectional vane and the electrically recording vane. In the later part of the work the gustiness vanes were mounted upon a rotating mast so as to keep them approximately in line with the average wind direction.

"It should be pointed out that since our thermometers are aspirated at a fairly high rate, there is an uncertainty as to what level the air which is drawn into the thermometer comes from. This is not serious at 1, 2, 3½, and 6 meters. . . . But at 10 cm the temperature gradient is often very steep and not very constant, and our measurements at 10 cm represent an average over a small region.

" . . . . Never in this work has a high inversion been observed with the wind velocity at 2 meters greater than 4 mph . . . . In this field we had green grass which was bent over to form a thick mat above the earth. In addition to being a good radiator, the grass had a low heat capacity and low heat conductivity. . . . . The soil in this region is comparatively light (and dry). . . . The afternoon temperatures during June and July are high, generally 100 to 105 F in the shade." (AUTHOR'S NOTE: Once in July a diurnal range of 98 to 28 F was recorded by this party. This confirms the report by J. S. Winters of one light frost in the Yolo Bypass each summer, on subirrigated bean vines.) . . . "Several times a week in July around 2 to 3 a. m. the wind would drop, the temperature gradient would build up and there would be a moderately high inversion (3½ F, between 0.1 and 1.0 m) which would last a few hours."

*Excerpt from July 14, 1943, Report.* "Common diffusion theories assume that the velocity gradient is negligible in the diffusion process. This is, of course, quite untenable for the extreme conditions reported here. . . .

"If one assumes the velocity profile, $U_x = U_o z^n$, where $z$ is the height, and assumes that the diffusion of momentum and matter follow the same laws, then the diffusion coefficient must take the form $D = D_o z^{1-n}$.

"Since our source actually produced a somewhat diffuse cloud, the constant $x_o$ is introduced. This represents the distance in yards from an ideal line source needed to give the actual diffuseness present at our source. Since rate of diffusion is less (for strong inversions) . . . one should adjust $D_o$ and $x_o$ to best agree with the data. It appeared that the simple assumption, $x_o = 100\ (U_2 - U_1)/U_1$ was reasonably good.

"Our measurements of the 4 to 1 meter velocity ratio seem to correlate with gas diffusion and temperature gradient better than the 2 to 1 meter data". (AUTHOR'S NOTE: Diffusion in forested area is reported by the same research group under the date September 14, 1943.)

(Continued on page 244)

TABLE 2 - ATMOSPHERIC CONDITIONS AND DIFFUSION OF BUTANE IN YOLO BY-PASS
OBSERVED BY: LATIMER, RUBENS, PITZER, GWINN AND ASSISTANTS.

| SHOOT No. | TIME | WIND $U_{2m}$ m.p.h. | WIND $\frac{U_{2m}}{U_1}$ | WIND $\frac{U_2}{U_1}$ | WIND $\frac{U_4}{U_1}$ | TEMPERATURE INVERSION 10-01m °F | 2-1m °F | 3½-2m °F | 6-3½m °F | GUSTINESS $G_{yb}$ | GUSTINESS $G_{zb}$ | CONCENTRATIONS, ϕ mg/liter AT 1FT. HEIGHT 50yds. | 100yds. | 150yds. | AT 3 FT. HEIGHT 50yds. | 100yds. | 150yds. | AT 6 FT. HEIGHT 50yds. | 100yds. | 150yds. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June 24 | | | | | | | | | | | | | | | | | | | |
| 1 | 8:45 p.m | 9.30 | 0.75 | 1.25 | 1.54 | 1.0 | 0.3 | 0.3 | 0.2 | 0.63 | 0.48 | 0.48 | 0.25 | 0.12 | 0.46 | 0.25 | 0.12 | 0.41 | 0.21 | 0.12 |
| 2 | 9:05 p.m. | 8.10 | 0.75 | 1.25 | 1.54 | 1.1 | 0.3 | 0.3 | 0.3 | 0.63 | 0.48 | 0.36 | 0.16 | 0.17 | 0.36 | 0.14 | 0.17 | 0.31 | 0.14 | 0.17 |
| 3 | 9:46 p.m. | 3.20 | 0.65 | 1.50 | 2.08 | 2.8 | 0.9 | 0.6 | 0.7 | 0.32 | 0.23 | 1.56 | – | 0.18? | 1.30 | – | 0.18 | 0.78 | – | 0.18 |
| 4 | 10:00 p.m. | 3.40 | 0.62 | 1.43 | 1.43 | 2.7 | 1.0 | 1.0 | 1.1 | 0.32 | 0.23 | 0.78 | 0.46 | 0.39 | 0.65 | 0.46 | 0.39 | 0.52 | 0.39 | 0.39 |
| | June 25 | | | | | | | | | | | | | | | | | | | – |
| 5 | 9:20 p.m. | 3.8 | 0.66 | 1.53 | 2.32 | 4.0 | 1.6 | 1.7 | 2.3 | 0.32 | 0.22 | 2.60 | – | 1.60 | – | – | 0.90 | 0.30 | – | – |
| | | | | | | | | | | | | 2.40** | | 1.60 | 1.35 | | 1.16 | 0.12 | | 0.34 |
| 6 | 9:56 p.m. | 3.25 | 0.61 | 1.66 | 2.78 | 3.9 | 1.8 | 1.9 | 2.7 | 0.21 | 0.15 | 5.20 | 4.70 | 3.20 | – | 2.30 | 1.30 | 0.26 | 0.31 | – |
| 7 | 10 24 p.m. | 3.03 | 0.54 | 1.68 | 2.54 | 4.0 | 1.8 | 1.5 | 2.0 | 0.18 | 0.08 | 5.50 | 4.30 | 3.10 | 1.50 | 2.70 | 2.10 | 0.25 | 0.30 | 0.45 |
| | | | | | | | | | | | | 4.80** | 3.9 | 3.3 | 1.80 | 1.90 | 1.90 | 0.15 | 0.60 | 0.12 |
| 8 | 11 14 p.m. | 1.95 | 0.58 | 1.95 | 3.61 | 3.8 | 1.0 | 1.1 | 1.5 | 0.25 | 0.17 | 3.10 | 2.20 | 1.40 | 2.30 | 2.00 | 0.91 | 0.62 | 0.78 | 0.71 |
| | Jun. 26 | | | | | | | | | | | | | | | | | | | |
| 9 | 9:58 p.m. | 3.50 | – | 1.7 | – | >5. | ~5. | 2 to 4 | 1.5 | 0.08 | 0.01 | ≫5.20tt | ≫5.20 | 4.40 | ~1.00 | ~3.10 | 0.80 | 0 | ~0.13 | 0.26 |
| | June 27 | | | | | | | | | | | | | | | | | | | |
| 10 | 10:45 p.m. | 4.00 | – | 1.45 | – | 2.7 | 0.9 | 1.1 | 2.6 | 0.28 | 0.16 | 1.80 | 1.45 | 1.10 | 1.80 | 1.30 | 1.10 | 0.65 | 0.88 | 0.70 |
| | June 29 | | | | | | | | | | | | | | | | | | | |
| 11 | 3:00 p.m. | 6.73 | 0.858 | 1.17 | 1.37 | -4.2 | -0.4 | -1.1 | -0.2 | 0.90 | 0.45 | 0.23 | 0.08 | 0.05 | – | 0.08 | 0.08 | 0.26 | – | 0.08 |
| | July 3 | | | | | | | | | | | | | | | | | | | |
| 12 | 10:23 p.m. | 4.30 | 0.77 | 1.25* | 1.53 | 1.4 | 0.6 | 0.6 | 0.3 | 0.58 | 0.36 | 1.43 | 0.46 | 0.52 | 1.17 | 0.46 | 0.52 | 0.78 | – | 0.52 |
| 13 | 11:04 p.m. | 3.50 | 0.66 | 1.39 | 1.73 | 2.5 | 1.0 | 1.0 | 0.6 | 0.59 | 0.24 | – | 0.78 | 0.31 | – | 0.78 | 0.39 | – | – | 0.39 |
| | July 4 | | | | | | | | | | | | | | | | | | | |
| 14 | 3:40 p.m. | 5.2 | 0.89 | 1.17 | 1.42 | -5.0 | -0.8 | -0.5 | -0.6 | 0.52 | 0.42 | 0.26 | 0.05 | 0.05 | 0.26 | – | 0.08 | 0.26 | – | 0.05 |
| 15 | 8:18 p.m. | 5.3 | 0.84 | 1.25 | 1.59 | 1.3 | 0.4 | 0.5 | 0.3 | 0.60 | 0.44 | 0.52 | 0.44 | 0.31 | 0.52 | – | 0.31 | 0.41 | – | 0.31 |
| 16 | 8:48 p.m. | 5.9 | 0.82 | 1.29 | 1.63 | 1.5 | 0.6 | 0.4 | 0.5 | 0.58 | 0.40 | 0.78 | 0.70 | 0.13 | 0.65 | – | 0.13 | 0.52 | – | 0.13 |
| 17 | 9:43 p.m. | 4.3 | 0.82 | 1.31 | 1.74 | 1.9 | 0.5 | 0.5 | 0.6 | 0.50 | 0.40 | – | 0.39 | 0.65 | 0.70 | – | 0.57 | – | – | 0.56 |
| | July 6 | | | | | | | | | | | | | | | | | | | |
| 18 | 7:19 a.m. | 5.55 | 0.85 | 1.16 | 1.44 | -0.8 | -0.3 | -0.4 | -0.2 | 0.70 | 0.46 | 0.39 | 0.26 | 0.13 | 0.23 | – | 0.13 | 0.10 | – | 0.13 |
| 19 | 7:49 a.m. | 5.86 | 0.81 | 1.19 | 1.33 | -1.5 | -0.4 | -0.4 | -0.4 | 0.66 | 0.43 | 0.52 | 0.26 | 0.10 | 0.52 | – | 0.08 | 0.07 | – | 0.08 |
| 20 | 7:56 a.m. | 5.69 | 0.79 | 1.20 | 1.38 | -2.0 | -0.4 | -0.5 | -0.4 | 0.70 | 0.46 | 0.26 | 0.26 | 0.09 | 0.26 | – | 0.09 | 0.13 | – | 0.09 |
| 21 | 8:00 a.m. | 6.35 | 0.82 | 1.20 | 1.40 | -2.5 | -0.5 | -0.6 | -0.4 | 0.70 | 0.46 | 0.65 | 0.31 | 0.16 | 0.65 | – | 0.13 | 0.39 | – | 0.15 |
| 22 | 8:45 p.m. | 6.20 | 0.86 | 1.24 | 1.55 | 1.7 | 0.5 | 0.4 | 0.3 | 0.70 | 0.52 | 0.65 | 0.36 | 0.29 | 0.65 | 0.38 | 0.32 | – | – | 0.28 |
| 23 | 9:05 p.m. | 5.40 | 0.85 | 1.27 | 1.63 | 1.6 | 0.6 | 0.5 | 0.4 | 0.49 | 0.39 | 0.39 | 0.49 | 0.47 | 0.39 | 0.47 | 0.41 | 0.16 | – | 0.36 |
| 24 | 10:50 p.m. | 7.03 | 0.84 | 1.23 | 1.52 | 1.2 | 0.5 | 0.5 | 0.3 | 0.63 | 0.43 | 0.57 | 0.31 | 0.28 | 0.52 | 0.28 | 0.23 | 0.23 | – | 0.19 |
| | July 7 | | | | | | | | | | | | | | | | | | | |
| 25 | 5:48 a.m | 3.55 | 0.83 | 1.35 | 1.91 | 1.5 | 0.5 | 0.7 | 0.8 | 0.41 | 0.27 | 1.30 | 1.17 | 0.78 | 1.10 | 0.35 | 0.63 | 0.91 | – | 0.62 |
| 26 | 6:12 a.m. | 3.57 | 0.87 | 1.39? | 1.64 | 1.0 | 0.2 | – | – | 0.50 | 0.41 | 1.17 | 0.87 | 0.31 | 1.17 | 0.70 | 0.24 | – | – | 0.21 |
| 27 | 6:20a.m. | 3.88 | 0.92 | 1.30 | 1.59 | 0.8 | 0.2 | – | – | 0.50 | 0.40 | 0.91 | – | 0.57 | 0.91 | – | 0.52 | – | – | 0.52 |
| 28 | 6:53 a.m. | 3.55 | 0.86 | 1.23 | 1.23? | 0.2 | 0 | 0 | 0 | 0.58 | 0.43 | 0.39 | 0.36 | 0.26 | 0.26 | 0.27 | 0.21 | 0.39 | – | 0.16 |
| 29 | 7:18 a.m. | 4.51 | 0.71 | 1.12 | 1.29 | -0.9 | -0.4 | -0.3 | -0.2 | 0.67 | 0.43 | 0.46 | 0.32 | 0.18 | 0.39 | 0.24 | 0.13 | 0.39 | – | 0.13 |
| 30 | 7:44a.m. | 5.47 | 0.86 | 1.13 | 1.43 | -1.6 | -0.4 | – | – | 0.57 | 0.38 | 0.21 | 0.18 | 0.21 | 0.21 | 0.23 | 0.18 | 0.23 | – | 0.18 |
| | July 10 | | | | | | | | | | | | | | | | | | | |
| 31 | 9:26 p.m. | 1.51 | 0.50 | 1.8 to 2.26 | 2.7 to 4.64 | >5. | 0.8 to 1.2 | – | – | .07 to .12 | 0.06 | ≫5.20 | ≫2.60 | >5.40 | 3.60 | ~2.60 | 2.60 | 0.18 | – | 0.30 |
| 32 | 11:59 p.m. | 3.10 | 0.68 | 1.90 | 2.82 | – | – | – | – | – | – | >6.00 | 2.60 | 4.90 | 0.80 | 2.30 | 2.70 | 0 | – | 0.10 |
| | July 21 | | | | $U_4/U_2$ | | | | | | | | | | | | | | | |
| 10:00 to 10:35 p.m. | | 3.23 | – | 1.43 | 1.91 | 1.0 | 0.9 | 0.4 | 0.8 | – | – | 0.18 of 650 yds.t | | | 0.18 of 650 yds.t | | | 0.20 of 650 yds.t | | |

ϕ (The rate of emission in the July 14, 1943 report is 0.5 lb./min. yd.)
*- Probably greater, corrected to 1.32
** Calculated by Pitzer in report of July 14, 1943.
t- There is some uncertainty with regard to the detectors being located on the axis of the cloud and the zero on some of the detectors appeared to have changed.
tt- Concentration ratios 1 to 3 feet; and 3 ft. to 6 ft. heights were greater than 10 of 50 yds. By 150 yds. the first ratio was about 3 and the second (3 ft. to 6 ft.) about 6.

# Use of the Airplane for Pest Control

By O. C. French
MEMBER A.S.A.E.

USE OF the airplane as a machine for applying insecticides dates back to the period following World War I. According to an article by Popham in "Agricultural Chemicals" for June, 1946, the first plane to apply dust was a World War I training plane (Curtiss H model) used in 1921 to apply lead arsenate to catalpa trees near Dayton, Ohio. In 1922 the U. S. Bureau of Entomology initiated tests of airplane dusting for cotton boll weevil control, and in 1924 at least one company carried on dusting operations on a commercial basis.

During the 1920's use of aircraft for dispensing insecticidal dusts developed steadily. Most of the improvements in aircraft design to suit this new use have been made by individuals, since the number of planes demanded has been so limited that aircraft manufacturers have devoted little engineering design effort to assist in this development.

By 1939 there was an estimated 200 planes in the United States equipped for crop dusting. Now there are over 75 agricultural aircraft companies in California alone. Prior to 1940 most aircraft dusting was in the cotton and vegetable growing areas of the Pacific Coast, South, Southwest and Atlantic Seaboards. In 1939 California reported 223,000 acres of crop and range lands treated by planes. Involved were 25 different crops, about 20 different pests, and 15 different insecticides and fungicides.

From the beginning, we have witnessed a slowly increasing use of the plane for dispensing liquids as well as dusts. I recall seeing airplanes applying concentrated liquid insecticide experimentally in California 15 years ago. The spectacular results obtained by crop-dusting planes in the beginning were not accepted without some criticisms and alarm. The drift of dust from a field receiving treatment to other kinds of crops in adjacent fields caused trouble in the beginning and has continued to do so. It was also recognized then as now that large-scale destruction of insects certainly destroys many beneficial ones, as well as destructive pests.

Even with the lack of aircraft design assistance and in most cases with very limited financial resources, the aircraft operators have come a long way during the past 25 years. They deserve our commendation for their pioneering efforts.

*Dusting.* One of the earliest publications which is available on airplane dusting is USDA Bulletin 1204 published in 1924. It describes some of the early devices adapted to World War I planes for dispensing dry dust on cotton plantations. The first test flights were made with limited quantities of poison dust carried in bags in the plane and either dumped over the side by hand or emptied out through an opening in the bottom of the fuselage. Obviously after a few flights it was found advisable to construct hoppers to carry the dust and distribute it into the air at a controlled rate.

*Hoppers.* The first hopper was built to clamp onto the outside of the fuselage and had a hand crank to operate the agitator and feeding device. The next step was to build in a hopper in the observer's seat of a two-place ship. Sufficient room had to be reserved to permit a man to stand up in the rear cockpit in order to turn the crank-operated dust feeder. The outlet from this hopper was merely a circular pipe extending through the bottom of the fuselage.

The next hopper development was known as the air-suction hopper. This design eliminated all mechanical motions except for opening or closing the feed gate. The hopper shape was not changed much but the feeding device consisted of an air tube extending down through the center of the hopper. Air flowing through this tube caused a suction which drew dust into it near the bottom of the hopper. No provision was made for distribution of the dust when it was discharged through the fuselage into the air stream, other than depending on the propeller slipstream turbulence to do this job.

The planes used for this early work were commonly called Curtiss H, or more properly Curtiss JN6H. They would only carry about 350 lb in addition to the pilot. The planes used the Hispano 150-hp, 8-cylinder, V-type engine.

*Spreaders.* The next improvement on dust hoppers and metering devices was the introduction of the venturi spreader located directly below the hopper and outside of the fuselage (Figs. 1 and 2). A reel-type agitator driven by means of a small propeller blade was soon added. This system is essentially that which is used by practically all aircraft dusters today. Of course there has been much to learn regarding shapes and sizes and position of venturies, agitators, etc. A problem which these early operators were faced with was satisfactory shutoff gates. For applying a free-flowing dust such as sulfur, it is exceedingly difficult to design a gate-closure

This paper was presented at a meeting of the Pacific Coast Section of the American Society of Agricultural Engineers, at Davis, Calif., February, 1947.

O. C. French is assistant agricultural engineer, California Agricultural Experiment Station.

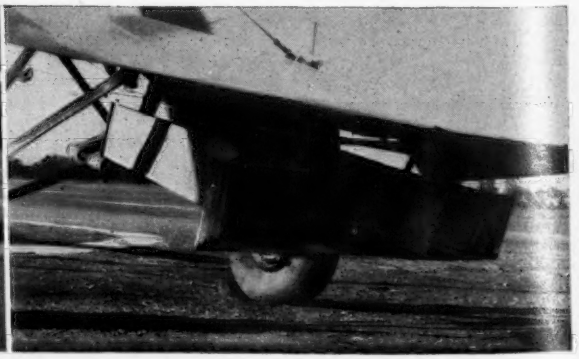


Fig. 1 *(Left)* "Venturi" spreader for dusts and seeding. The spreader is mounted so that the exit is pointed slightly downward when the plane is in level flight • Fig. 2 *(Right)* View of the exit end of a "venturi" spreader on an airplane. Actually this spreader is not a venturi; dust is fed into the throat of this spreader by means of venturies. These venturies are partially visible in Fig. 1

Fig. 3 *(Left)* View of an airplane applying calcium arsenate dust on tomatoes. Good air conditions prevailed, but note the amount of dust still suspended after several swaths have been laid down by the plane • Fig. 4 *(Right)* This is the same plane as shown in Fig. 3, having to clear a border of olive trees. The dust being discharged at the increasing elevation is vulnerable to air movement which may carry it to adjoining fields

device which will prevent the dust from sifting through, and yet be free enough to permit easy opening. This problem has been solved by means of felt seals around the sliding gate edges. The dust which one sees coming from a plane while making turns at the ends of fields is that which has built up on the metal venturi surfaces while the gate is open. Other important improvements on aircraft dusting devices include the increased carrying capacity (now commonly about 800 to 1000 lb), better agitator drives and bearings, and location of engine exhaust pipe outlets to minimize the danger of carbon sparks igniting flammable dusts.

*Advantages and Limitations of Airplane Dusting.* The advantages of aircraft dusting are numerous. The outstanding factor is obviously speed of application, since timeliness is usually important. Secondly, many crops should be treated when ground equipment cannot be transported over the soil, either because of the nature of the crop or because of wet soil conditions. Thirdly, the air turbulence created by the propeller can effectively force dusts into dense plant foliage, without mechanical damage to the foliage.

Dusting by aircraft does have some serious limitations. The air turbulence created by the airplane also works to its disadvantage, because much of the dust is of such small particle size that it floats easily in the high-velocity air movement created by the moving plane. Once these small dust particles are carried upward from the ground by air currents, their time for settling out is very long (Fig. 3), hence drifting becomes a major problem. It is questionable whether sufficient evidence is at hand relative to the relation of dust particle size to toxicity, to demand that our present dusts should be made up of such small particles. From aerodynamic principles the small particles are much less likely to be intercepted by plant foliage than are heavier particles. (See preceding paper in this issue, entitled "The Drifting of Poisonous Dusts Applied by Airplanes and Land Rigs" by F. A. Brooks.)

Further difficulties with plane application arise from trees and power lines which so frequently bound the edges of fields to be treated (Fig. 4). Timing the application is particularly difficult because of natural air currents and wind conditions. The latter would not be so critical if other than very light dusts could be used.

The helicopter may eventually solve the problem of hazards surrounding the fields to be treated, but their forced eddies are about 20 ft deep when dusting hops, and they are not yet considerad satisfactory for dusting low-growing crops.

*Spraying.* The practice of applying liquid sprays by airplane is not new. Limited use of the plane for applying concentrated liquid insecticides and fungicides has been going on

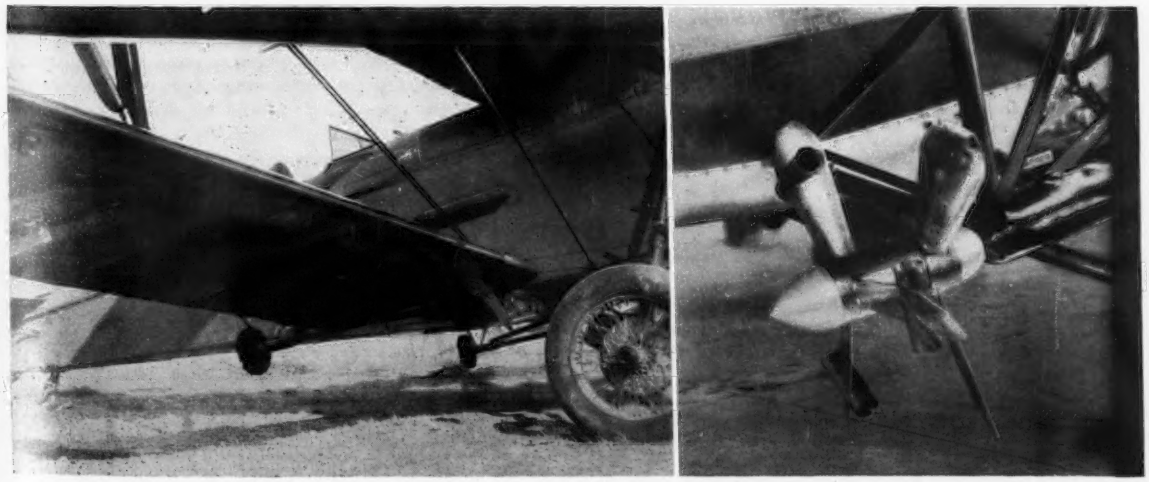


Fig. 5 *(Left)* A rotating brush-type dispersing device. For field spraying usually two units are mounted under each wing • Fig. 6 *(Right)* A rotating-type, liquid-dispersing device. Liquid is forced out from hub through prop blade to the little venturi tubes on each of the three blades. A screen is built into each venturi through which liquid passes and is atomized

for the past 15 years as previously mentioned. The application of DDT in liquid forms during the recent war has stimulated much interest in the use of aircraft for agricultural spraying. Unfortunately most agricultural pests require heavier dosages of material for their control than do mosquitoes. Furthermore, most agricultural treatment requires small individual fields to be treated, whereas in many cases mosquito-control treatments are applied over large areas with DDT dosages of only 1 to 2 qt per acre.

*Spraying Devices.* The types of planes being used for liquid application are in general the same as for applying dusts. There are several devices being used to atomize and distribute liquid sprays: (1) Rotating brushes (Fig. 5), (2) rotating spinners (Fig. 6), (3) booms and nozzles (Figs. 7 and 8). The first two devices are driven by small auxiliary propellers or fan blades at speeds varying from 2,000 to 3,000 rpm. Liquid is pumped into the hubs or centers of both the rotating brushes and/or spinners, and when the liquid is thrown from the periphery of these units, it is broken up and dispersed mainly by the propeller slip stream. The boom and nozzles are much like those used on ground sprayers except that shut-off valves must be located close to each nozzle in order that the spray start quickly and shut off sharply. Some form of pressure pump to force the liquid from multiple nozzles is necessary in order to provide uniform rates of flow and also make possible more adjustability in liquid particle size range. The pump pressure required may vary with the type of nozzles used and with the viscosity of liquid being dispensed. Pressures now being used vary from 20 to 100 psi. The degree of atomization may also be changed greatly by the location of the nozzles on the boom. For example, with nozzles discharging downward and at 90 deg to the air flow, the liquid is broken up much finer than when the nozzles are directed to discharge backward with the air flow.

In most cases single-stage centrifugal pumps are being used. Aluminum alloy pumps are being mounted inside of the engine cowling and are driven from a power take-off shaft from the engine by means of multiple V-belts. The piping system is arranged so that with a single control the pilot can operate a two-way valve. This valve permits discharge of the pump to be directed either into the boom or into a by-pass line leading to the liquid storage tank. This by-passed liquid also serves for agitating the material in the storage tank. A clutch is provided on the power take-off drive so that the full engine power can be utilized for the plane's take-off.

The arrangement and types of nozzles being used for the boom-type sprayers are varied. Some operators use whirl-jet cone-spray nozzles attached to the boom through a cutoff valve. Others use flat fan type nozzles. Some builders attach a cluster of 3 to 5 nozzles per cutoff valve, while others use only one nozzle per valve. Spring loaded cutoff valves as well as ordinary cock-type valves are being used. In most cases the booms are being constructed of streamlined strut tubing.

*Drop Size.* Some materials, such as selective weed sprays, seem to be more effective when applied as coarse sprays. This is fortunate because the drift problem is much less critical with the larger droplet sizes in the range of 300 to 500 microns. Insecticides, in general, give a more uniform and effective deposit when atomized to smaller droplet size, probably in the range of 50 to 300 microns. I do not believe anyone has yet determined the correct atomization specifications for aircraft operators to meet. Experimental work is now in progress to determine this information. This is a task which will require much cooperation in order to establish good standards.

Liquid spraying by planes has a distinct advantage over dust in that much of the problem of drifting is avoided. This is not to say that liquid sprays won't drift. Finely atomized spray will drift (see Fig. 4 of the paper by F. A. Brooks, elsewhere in this issue), if the plane is too high, and if the spray cannot be cut off quickly when the boundary of the field is approached. For aircraft spraying it is almost imperative that concentrated liquids be used in order to get an economical pay load. This is not new to us here in California where we have seen the origin and much development of concentrated sprays.

Since spray droplets are generally larger and many times heavier than dust particles, spraying can take place while air-current velocities are higher than permissible for dusting. Even though the width of spray swath is less than with dust, the actual acreage treated may be more during a given weather period.

There are several factors affecting the efficiency of liquid spraying by planes, some of which we are unable to control. These are wind velocity and direction of air stability. Anything other than stable air is adverse to deposition of small droplets. Aerial spraying is carried out relatively close to the ground and there are only short periods during the day when stable air conditions exist (in this portion of the atmosphere). On the other hand, a predominance of large droplets which have sufficient mass to overcome eddy air currents tends to reduce the efficiency of application of spray solution. It is necessary to compromise on the degree of atomization..

The spray swath width is influenced by the design and power of the plane, by the location of the dispersing device with relation to the slip stream, and by the height of the plane above the ground.

To study these factors under field operating conditions is considerably more difficult than with ground machinery. One has to work on much larger plot areas and hence the labor in checking results is great. Furthermore an air-to-ground radio communication system is a necessary piece of equipment to adequately direct aircraft spraying and dusting experiments.

*(Continued on page 244)*

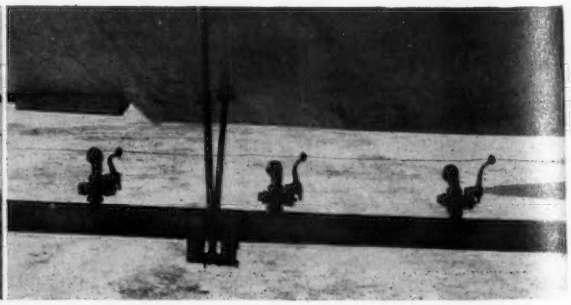


Fig. 7 *(Left)* A boom-type airplane sprayer. Spring-loaded valves at base of each nozzle are operated by a single cable control. The pump is mounted on the landing gear and driven by an auxiliary propeller. Present practice is to mount the pump inside the engine cowling and to drive a power take-off from the engine • Fig. 8 *(Right)* Close-up view of the nozzle arrangement of boom in Fig. 5. Nozzles are attached to top side of boom and discharge to the rear. This location of nozzles is used to apply 2,4-D spray where large size spray droplets are desired

# Dry Matter Loss in Haymaking Due to Bacterial Action

By Harry Miller
MEMBER A.S.A.E.

CONSERVATION of values is an objective in all processing operations. Haymaking can properly be classified as a processing operation of very great economic importance. It is a means of bringing feed to animals that cannot be turned out to graze, and to provide feed for all grass-consuming animals between growing seasons. Naturally we want to conserve all the elements of nutrition in the finished product as nearly as possible at the same level as they were in the living plant before it was cut loose from the ground. The decomposition of organic matter due to microorganisms after life has ceased to exist, whether of plant or animal origin, is well known. This decomposition continues more or less rapidly depending on conditions, until reduction is complete or until it is terminated by conditions under which microorganisms cannot carry on their life processes. As to what these conditions are, we need look only at the four well-known methods of preserving food which are (1) refrigeration, (2) chemical treatment, (3) canning, and (4) dehydration. The first of these is merely a matter of producing sufficiently low temperatures so that microorganisms can neither reproduce nor carry on decomposition.

Preservation by chemical treatment can either be induced or created by addition of preservatives. The ensiling process is an example of induced chemical preserving. The product is first of all placed into the silo. Decomposition of the more easily fermentable carbohydrates sets in immediately and carbon dioxide is produced. This displaces the air in the already compacted material and microorganisms that require free air for their life processes are immediately inactivated. Lactic acid is also produced which has good germicidal properties, and finally a concentration is reached so as to inactivate all microorganisms including those producing it. Preservation by the addition of preserving agents usually consists of adding sugar or salt at such concentrations that the water within the microorganisms diffuses through the cell membrane to the exterior. The organism is thus desiccated, and while it may remain alive it lies dormant. Jellies, jams, and many confections are thus preserved.

Preservation by canning is essentially a process of sterilization by heat treatment. Enzymes that break down complex organic materials and microorganisms are destroyed. The material is stored in sterile containers and will thus keep almost indefinitely.

Everyone recognizes preservation by dehydration. However, dehydration in the final analysis is very similar to preservation by addition of preserving agents. Plant juices are merely soluble materials, mainly sugars and salts in a water solution. We can stop bacterial action by a sufficiently high concentration of either sugars or salts. We can do this by adding soluble material or by removing sufficient water to build up the concentration to the necessary point by a process we call dehydration.

Authorities on the subject of soil microbiology agree that it is one of the most complex subjects; also that practically every known organism occurs in the soil. It is only natural that plant materials coming from the field will be covered with many organisms of every type and that all are ready to do their part in destroying these materials as long as conditions exist under which they can work. There are the molds that can break down coarse materials to simpler compounds which other organisms can use to complete the destruction to carbon dioxide and water. An example of mold activity is the breaking down of starch to glucose in accord with the following equation:

$$(C_6H_{10}O_5)X + XH_2O \xrightarrow[\text{enzymes}]{\text{mold}} XC_6H_{12}O_6$$

starch — water — enzymes — glucose

The glucose formed in this reaction may be partly decomposed by the mold and partly by other organisms usually through several stages in accord with the following equation:

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{microorganisms}} 6CO_2 + 6H_2O$$

glucose — carbon dioxide — water

It will be seen that the first reaction requires water and the second produces water considerably in excess of that required by the first reaction. The relationship is symbiotic. The above types of decomposition set in promptly. There is also a parallel reaction affecting the proteins in accord with the following generalized equation:

$$\text{Proteins} + \text{water} \xrightarrow{\text{microorganisms}} \text{amino acids}$$

Bacteria in the process of reproduction require amino acids for their own bodies and draw on the products of the above reaction. Consequently there is a transformation from grass protein to a bacteria protein.

There is a serious question regarding the digestibility of these latter proteins. Consequently it is to be expected that there will be a decrease in the nutritional value of the protein although the level may not be affected according to the standard analytical procedure. In advanced stages of bacterial destruction amino acids are completely decomposed into volatile products like ammonia, amines, carbon dioxide, and water.

In observing alfalfa dehydration operations in Nebraska, the hay had developed considerable heat during the time required in coming a few miles by truck from the fields to the dehydrating plant, indicating microbiological oxidation and consequent destruction of dry matter. All considerations relating to this problem point to a race between microbiological destruction of dry matter and the preserving operation regardless of the form of preservation. The longer preservative conditions are delayed, the greater the destruction of dry matter is likely to be.

In this connection the data presented in the Vermont Agricultural Experiment Station Bulletin No. 494 is of interest. Dry matter losses due to microbiological decomposition were determined in various types of hay. The data includes sun-cured, ensiled, and artificially dried hay. The dry matter disappearance in trial silos without preservation was 23 per cent. In the case of sun-cured hays from standing grass to fully cured hay out of the mow it varied from 9 to 36 per cent. In case of artificially dried hays the losses ran from 3 to 7 per cent.

In the hay processing research work of the chemurgy department of the University of Nebraska, the main objective is to get a variety of salable materials, including industrial as well as food and feed products. We have the problem of destruction by bacterial action as much as in regular haymaking operations. We are working on a process of pressing green alfalfa in a continuous screw press. Two fractions are thus

---

This paper was presented at the Third Barn Hay-Curing Conference sponsored by the American Society of Agricultural Engineers at Chicago, Ill., December, 1946.

HARRY MILLER is research engineer and acting head, chemurgy department, University of Nebraska.

obtained, a liquid and a solid fraction. In the case of alfalfa, 40 per cent of the dry matter is expelled with the juice. The concentration of solids in the juice has been found to be from 25 to 30 per cent, and about equally divided between suspended and soluble solids. It is probable that this expeller juice carries in solution nearly the amount of solids as the juice contains as it occurs in the plant. These dissolved solids do not represent all the decomposable matter. Through the action of organisms, like molds, insoluble matter like starch is rendered soluble with a subsequent complete decomposition by other organisms.

The available data and observations indicate that in order to conserve a maximum of dry matter it is necessary to begin and achieve preservative conditions as soon as possible after the plant is cut from the ground.

## Drifting of Poisonous Dusts

*(Continued from page 239)*

From the data of the Latimer group, Table 2, the observations selected as representative of strong stability in the early morning are Nos. 5, 6, 7, 8, and 10. These indicate an average $G_x = 0.02$ calculated by formula [4]. Test No. 9 is excluded as an extreme case for which the observed vertical gustiness was less than 1/15 the average of the other five runs. For moderate stability the early evening run Nos. 15, 16, 17, 22, 23, and 24 together indicate $G_x = 0.04$ approximately. For the daytime unstable condition of small-scale convection, run Nos. 11, 14, 18, 19, 20, and 21 indicate $G_x = 0.10$ approximately. No direct observations were made by the Latimer group of diffusion horizontally, transverse to the wind. The estimate of lateral gustiness $G_y$ must, therefore, be based on their observed bivane ratio, $G_{yb}/G_{xb}$. For the three selected groups of observations the observed bivane ratios are 1.60, 1.36, and 1.56, respectively. Applying these ratios to the calculated vertical diffusion gustiness, $G_x$, the estimated lateral diffusion gustiness, $G_y = 0.03$, 0.054, and 0.16 for very stable, moderately stable, and small-scale convective conditions.

## Airplane for Pest Control

*(Continued from page 242)*

CONCLUSIONS

The airplane has a definite place in the agricultural pest control field today. Its use for applying dusts has been recognized for many years. Limited use has already been made of aircraft for liquid spraying during the past 15 years, and with the recent developments of herbicides for weed control the demand for plane spraying has increased tremendously. The development of some insecticides such as DDT and other materials in liquid suspension forms for vegetable and field crops will cause a greatly increased demand for aircraft spraying this year. It would appear that liquid spraying will soon replace poisonous dusts as a pest control measure primarily because the drifting problem is nearly eliminated.

At the present time we find the airplane being successfully used for applying herbicides on grain fields, rice fields, alfalfa, irrigation and drainage ditches. In the field of insecticides and fungicides the plane has great potential usage for field and vegetable crop spraying. Application of insecticides and fungicides on deciduous trees by plane still requires a great deal of study and experimental work.

While the seeding of crops is not pest control, it is interesting to note that many thousands of acres of barley and legumes have been seeded this year by plane. Of course, rice seeding has been a standard practice for years. Rather extensive broadcasting of fertilizer is also being done. These diverse agricultural applications for the airplane make it possible for the commercial operators to use their equipment over a greater portion of the year, and as a result lead to better equipment and less cost to the farmer.

## $CO_2$ to Prevent Scald of Stored Apples

IT SHOULD be emphasized that no visible carbon dioxide injury to the flesh and no effect on flavor was observed with the following varieties: Cortland, Rhode Island Greening, Northern Spy, Delicious, Jonathan, Stark, Winter Banana, Gravenstein, and Wealthy. . . . In every case the treatments with carbon dioxide resulted in firmer fruits as measured by pressure test. This increased firmness means a longer storage period for the fruits concerned.

It is believed that, with better methods of speeding evolution of carbon dioxide from dry ice, one ton would be enough to provide an atmosphere of 50 per cent of this gas for five days in the room used. Assuming that the room is filled with 3300 bu of fruit, the cost of the dry ice would be less than two cents per bushel.

Additional work is being carried on this season to determine the best means of providing proper concentrations of carbon dioxide in a cold storage room. The response of additional varieties including Grimes, York, Stayman, and Black Twig is being studied. It is hoped that recommendations for limited commercial trials may be made before the 1947-48 storage season. — From a paper by E. P. Christopher, in "Refrigerating Engineering" for April, 1947.

A radio telephone is used for communication between the headquarters of Seabrook Farms Company at Bridgeton, N. J., and 18 mobile units which operate in eight vegetable divisions and one orchard division, comprising 19,000 acres. The two-way telephone sets are used for directing field operations and reporting progress and problems by this company, which is a large producer for the frozen foods market

# Soil Erosion Studies—Part III

## Some Effects of Soil Erosion on Infiltration and Surface Runoff

By W. D. Ellison
MEMBER A.S.A.E.

THE purpose of this paper is to show that soil erosion has a pronounced effect on decreasing infiltration and increasing surface runoff. The splash erosion process which muddies surface waters and breaks down soil clods and aggregates will thereby reduce infiltration. Erosion that scours rills and gullies, in addition to draining small surface basins and thereby reducing surface storage, will also cause velocities of surface flow to be increased; both of these changes will tend to increase surface runoff.

*Definitions.* First of all, let us clarify the use of several terms. The "infiltration process", as the term is used in this paper, refers to water *entering* a soil mass by filtering through pores in the surface. Under exposure to rainfall and other elements of weather, there will usually be developed in the surface soils a thin layer of relatively low permeability. The least permeable plane in this layer will control the soils infiltration capacity. Pores in the surface soil are usually unstable, and changeable, and their water-filtering capacities may vary with each change that takes place. In some soils the least permeable plane is found on the very surface, while in other soils it is found just below the surface. In most of our practical field work the least permeable plane that affects the *infiltration* capacity will be found in what we might call the "skin" of the soil, a thin layer on the outer surface which is materially changed in structure by its exposure to the elements of weather. The depth of this layer may vary with the different soils, but it will usually be less than an inch deep. Thus the infiltration process is a surface phenomenon, and the term *infiltration capacity* refers to a rate capacity. It can be described by saying it is a measure of permeability of the least permeable plane of surface soil, and it will usually be expressed in terms of inches depth of water per hour that will filter through this plane.

After the water has once filtered through this least permeable surface plane, its disposal within and through the profile materials is referred to as infiltration disposal. Thus we see that infiltration disposal capacity is a profile phenomenon, and that the term "capacity" as used here also refers to a rate, and it is usually measured in inches depth of water per hour that the profile materials will dispose of. Disposal of infiltration is achieved through storage within and transmission through the profile materials. The amounts of water that are stored will depend on a soil's storage capacity. This will represent the quantity of water that some specified depth of the soil may absorb.

The runoff process, as the term is used in this paper, is limited to surface flow which is in the process of running off some designated area. Here we make a distinction between the terms surface flow and surface runoff. A quantity of surface flow does not become a quantity of runoff until it flows off the drainage area to which we apply the term "runoff". Runoff is applied either to a rate when referring to the process or to a quantity of water when referring to the amount of runoff.

*Splash Erosion and Infiltration Capacities.* To measure the infiltration capacity of a soil, we must eliminate subsurface (profile) obstructions which would restrict infiltration rates. For example, we cannot measure the capacity of a strainer, if we have another strainer of lesser capacity immediately below it. Nor can we determine infiltration capacity of a soil's outer surface if profile conditions below the surface plane restrict infiltration rates. But where the disposal capacity is *equal to or exceeds* the infiltration capacity of a soil, *the infiltration rate will equal the infiltration capacity* of that soil. This was the situation while experiments listed in Table 1 were being run. In this work one inch of topsoil was spread on a sand base about 18 in deep. In the sand there were tile drains to insure that the infiltration disposal capacity of the base materials would exceed the infiltration capacity of the soils. The infiltration rates underwent change, as shown for various time intervals.

TABLE 1. SUMMARY OF INFILTRATION DATA*[1]

| Test No. | Soil No. | Drop velocity, fps | Drop diameters, m | Rainfall intensity, iph | Infiltration rate at 5 min, iph | 15 min, iph | 30 min, iph | 1 hr, iph |
|---|---|---|---|---|---|---|---|---|
| 1 | I | 0 | 5.1 | 6.9 | 2.4 | 2.3 | 2.2 | 2.0 |
| 2 | I | 3.1 | 5.1 | 6.7 | 2.2 | 1.6 | 1.4 | 1.3 |
| 3 | I | 10.2 | 5.1 | 6.8 | 1.4 | .2 | .1 | |
| 4 | II | 0 | 5.1 | 6.7 | 3.5 | 3.2 | 3.0 | 2.8 |
| 5 | II | 10.2 | 5.1 | 6.4 | 1.8 | .7 | .6 | .6 |
| 6 | III | 20.4 | 5.1 | 5.8 | 1.4 | .0 | .0 | .0 |
| 7 | III | 0 | 5.1 | 6.8 | — | — | — | 6.7 |
| 8 | III | 3.1 | 5.1 | 6.9 | 5.7 | 4.6 | 3.5 | 2.7 |
| 9 | III | 6.1 | 5.1 | 6.5 | 4.9 | 2.7 | 2.1 | 2.0 |
| 10 | III | 10.2 | 5.1 | 6.7 | 2.0 | 1.0 | .7 | — |
| 11 | III | 20.4 | 5.1 | 6.5 | .7 | .3 | — | — |
| 12 | IV | 0 | 5.1 | 6.6 | 6.5 | 6.4 | 6.3 | 6.1 |
| 13 | IV | 3.1 | 5.1 | 6.4 | 6.3 | 5.2 | 4.4 | 3.7 |
| 14 | IV | 10.2 | 5.1 | 6.5 | 3.6 | 2.1 | 1.8 | — |
| 15 | IV | 20.4 | 5.1 | 6.5 | 1.5 | .7 | .7 | — |

*Analysis by R. L. Burling and W. D. Ellison.

*Factors Affecting Infiltration Capacities.* The primary factors which affect these infiltration capacities are of two groups: (1) Properties of the materials through which the water must filter, and (2) properties of the liquids to be filtered. Obviously then infiltration rates decrease either when the soil pores through which this water must filter are decreased in sizes or numbers, or when the surface water is made more muddy. Studies at Coshocton, Ohio, showed that both the muddiness of surface water and the properties of pores in the soil surface were very sensitive to raindrop impact characteristics, and that each underwent change with each increase in the impact energy of the falling raindrops.

*Splash Makes Surface Water Muddy.* Each time raindrop impacts are increased the surface water is made more muddy through splash erosion[2,3]. A high sensitivity of splash erosion to raindrop impacts is shown in Table 2. Here it may be seen that an increase in either drop size, drop velocity, or rainfall intensity tends to increase the amounts of soil splashed. These relationships were expressed by the formula

$$E = KV^{4.33} d^{1.07} I^{0.65} \qquad [1]$$

where $E$ = the relative amounts of soil splashed, during a 30-minute period
$K$ = a constant of the soil
$V$ = velocity of raindrops in feet per second
$d$ = diameter of raindrops, in millimeters
$I$ = inches depth of rainfall per hour.

---

This paper was prepared expressly for AGRICULTURAL ENGINEERING, and is the third of a series.

W. D. ELLISON is assistant chief, Division of Drainage and Water Control (Research), Soil Conservation Service, U. S. Department of Agriculture, Washington, D. C.

[1] Factors that Affect Surface Sealing and Infiltration of Exposed Soil Surfaces, AGRICULTURAL ENGINEERING, April, 1945.

[2] Recent Studies in Raindrops and Erosion, by J. Otis Laws, AGRICULTURAL ENGINEERING, November, 1940.

[3] Studies of Raindrop Erosion, AGRICULTURAL ENGINEERING, April and May, 1944.

TABLE 2. QUANTITIES OF SOIL IN RAINDROP SPLASH[2]

| Experiment | Velocity of drops, fps | Diameter of drops, mm | Intensity of rainfall, iph | Soil splash (E), g |
|---|---|---|---|---|
| 1 | 18.0 | 3.5 | 4.8 | 223 |
| 2 | 18.0 | 5.1 | 4.8 | 446 |
| 3 | 18.0 | 5.1 | 8.1 | 690 |
| 4 | 14.5 | 3.5 | 4.8 | 67.1 |
| 5 | 14.5 | 5.1 | 4.8 | 203 |
| 6 | 14.5 | 5.1 | 8.1 | 295 |
| 7 | 12 | 3.5 | 4.8 | 15.3 |
| 8 | 12 | 5.1 | 4.8 | 35.7 |
| 9 | 12 | 5.1 | 8.1 | 67.3 |

*Splashing Raindrops Break Aggregates.* The impacts of raindrops also tend to break down soil aggregates. Some results of this action are shown in Table 3. It is apparent that the effects of breaking down soil aggregates, as shown in this table, would tend to reduce permeability in the surface plane of a soil. The effects of this, along with the effects of muddying the surface water (as shown in Table 2), would work together in reducing the infiltration capacities listed in Table 1.

TABLE 3. AGGREGATE ANALYSIS BEFORE, DURING, AND AFTER RAINFALL[2] (Expressed in per cent)

| 2 mm | 2 to 1 mm | 1 to 0.5 mm | 0.5 to 0.25 mm | 0.25 to 0.105 mm | 0.105 mm and less |
|---|---|---|---|---|---|
| Before rainfall | | | | | |
| 13.34 | 6.33 | 6.69 | 8.01 | 12.05 | 53.55 |
| Materials contained in runoff | | | | | |
| .40 | 1.68 | 2.39 | 2.85 | 5.27 | 87.26 |
| Materials contained in raindrop splash | | | | | |
| 2.40 | 3.89 | 5.07 | 5.24 | 11.38 | 71.96 |
| Materials on surface after rainfall | | | | | |
| 19.85* | 4.38 | 4.47 | 4.09 | 12.62 | 54.56 |

*Aggregates include all stone fractions which have collected in excess on the surface during rainfall.

*Differences in Clay Content and Aggregation Cause Changes in Infiltration.* Infiltration capacities of the four soils shown in Table 1 are seen to vary with soil differences, as well as with each increase in drop impacts. A study of the properties of these four soils shows that state of aggregation and clay content of a soil are both important factors affecting the results. Relationships of these properties to infiltration capacities can be summarized as follows: To improve the aggregation tends to increase the soils infiltration capacity, while to increase the clay content without improving the aggregation will tend to decrease this capacity (Table 4).

TABLE 4. COMPARISON OF PHYSICAL PROPERTIES AND INFILTRATION RATES[1]

| Soil No. | Aggregates greater than 0.105 mm, per cent | Clay per cent | $E = 35$,* in/hr † | $E = 0.1$,* in/hr † |
|---|---|---|---|---|
| I | 44 | 14 | 1.7 | 0.2 |
| II | 67 | 12 | 2.8 | .7 |
| III | 80 | 12 | 5.2 | 1.4 |
| IV | 80 | 6 | 5.7 | 2.1 |

* The amount of soil splashed is a function of time, and the values of $E$ in this table are based on average 30-min time intervals (formula [1]).

† The infiltration rates are averages for all time intervals shown in Table 1; this average is 25 to 30 min for each test.

Results in Tables 1 and 4 seem to justify the conclusion that both impact energy of raindrops and properties of the soil will have an outstanding effect on the infiltration capacity of a bare field. In view of this, our conservation practices that will have an important effect on increasing the infiltration capacity of a soil must achieve either (a) a reduction in raindrop impacts or (b) a change in soil structure, such as will bring about a change in soil permeability. The discussion which follows will be restricted to factor (a), the raindrop impacts.

*Cause and Effect Relationships.* Since the infiltration disposal capacity exceeded the infiltration capacity of the soil for all experiments listed in Table 1, those infiltration rates may be accepted as representing the infiltration capacities of the soils. This being true, we may plot each of these capacities as a dependent variable, and the impact of raindrops as an independent variable, and our diagram will represent a cause and effect relationship. A typical curve of these relationships is shown in Fig. 1, where infiltration capacity is plotted as the ordinate and a factor of raindrop impact is plotted as the abscissa.

Before we can make the plottings shown in Fig. 1, we have to be able to measure the infiltration capacity of the

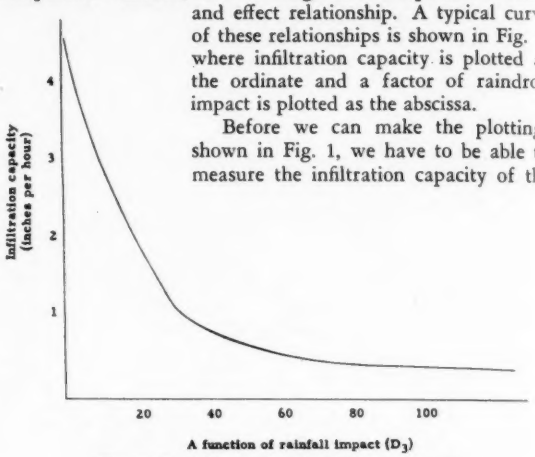



Fig. 1 Rainfall impact and infiltration capacity

soil and the impact energy of the falling raindrops. The methods used in measuring infiltration capacities of disturbed soil samples (results listed in Table 1) were described in the preceding discussion. Methods to be used on undisturbed field samples are to be discussed in some of the following paragraphs. The impact factor (represented by the symbol $D_3$) may be measured with the sand dish described in a previous paper[4].

Where a field contains growing crops or mulches, the $D_3$ factor is reduced by raindrop interceptions. Effects of these interceptions are represented by increases in $R$ values[4], and where the soil is partially covered, the impact factor will be equal to $D_3/R$. Each increase in the value of $R$ will reduce the effects of the $D_3$ factor and help to preserve infiltration capacities. Consequently the infiltration capacity of each soil will be a function of the $R$ value of its cover. Typical relationships for these factors are shown in Fig. 2.

To measure the infiltration capacity, where the soil can be removed and spread over a sand bed, is a fairly simple matter. But where the soil must be tested under a growing vegeta-

[4] Soil Erosion Studies — Part II, AGRICULTURAL ENGINEERING, May, 1947.

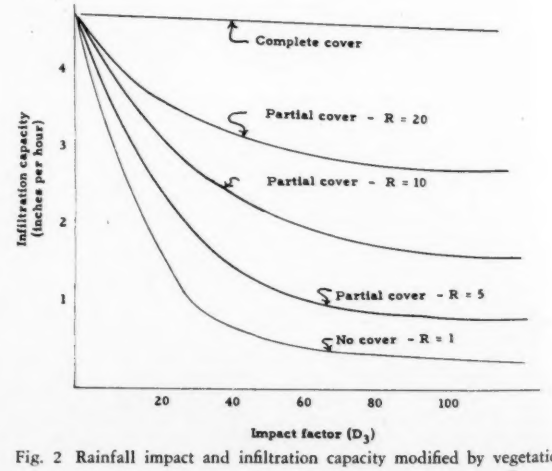



Fig. 2 Rainfall impact and infiltration capacity modified by vegetation

tion, where it cannot be removed and spread on a sand bed, the problem is more difficult. Perhaps the best procedure is first to test the disposal capacity of the profile materials under the vegetation, and if this is found to be in excess of the infiltration rates, then the infiltration rates measured on that soil will be equal to the infiltration capacity of the soil.

*Infiltration Disposal.* The infiltration disposal capacity may be measured by spading up about the top 1 inch of soil to make certain that surface seals developed through the beating actions of raindrops are destroyed, and the rainfall is then applied without impact. This application can be made with the rainfall applicator shown in the previous paper[4]. The apparatus is lowered to the soil so that the drops are released from the strings while they are in contact with the soil. Another way of eliminating impact is to lower the equipment to a height of only about two feet above the surface and then cover the soil with burlap, or completely cover it with a mulch before the drops are applied. The screen which supplies the raindrops is 4x4 ft, and the area to be spaded and protected with burlap or mulch will be approximately the same size.

A small plot about 1x1 ft, in the center of this larger area, may be used for measuring infiltration disposal. A sheet metal border of about 20-gage iron can be used for the borders of the 1x1-ft plot. This should be sunk into the soil about ½ in below the depth of spading. If the spading goes only 1 in deep, then this border should be set about 1½ in deep. It should also extend about 1½ in above the soil surface to confine the surface flow. A small ⅜-in tube will serve to remove runoff from this 1x1-ft plot, and infiltration disposal capacity will be equal to the rate of water application minus the rate of runoff.

The curve of infiltration disposal capacity may now be plotted as shown in Fig. 3. This capacity will be affected by the permeability of the soil (which is a measure of its transmission capacity when fully saturated) and by the volume of available storage within the soil. Wherever there is a plane or section of profile materials below the surface, that is less permeable than materials above it, then the permeability values as measured for the profile materials will be affected by the quantity of water in the profile. Storage capacity will also vary directly with the amount of water the profile contains. Since the effects of water in the profile will affect both the permeability and the storage factors in the same way, tending to reduce both, we may use the factor of variations in quantities of water in the profile as a primary cause for variations in the disposal capacity (Fig. 3). (N. B. It is important to recognize that while the quantity of water contained in the soil will represent a principal factor affecting infiltration disposal, variations in the distribution of this profile water may at times cause some variations in relationships shown in Fig. 3.)

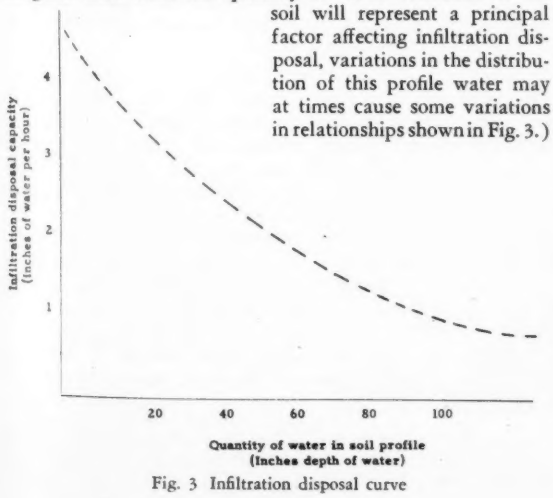



Fig. 3 Infiltration disposal curve

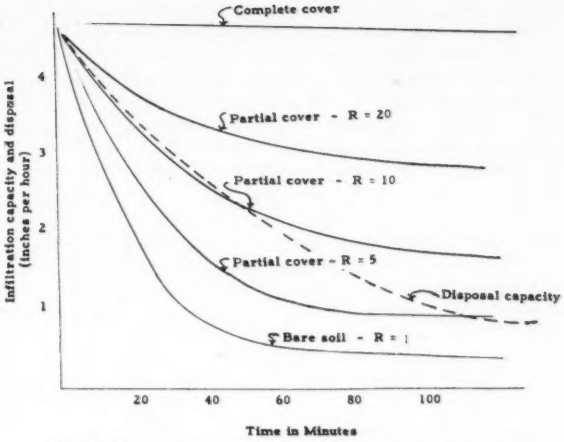



Fig. 4 Infiltration and disposal curves with various soil covers

The terminal disposal capacity shown at the right of Fig. 3 is approximately equal to the transmission capacity of the least permeable layer of the profile materials through which the water is filtering. If below this layer there is an increase in permeability of the profile materials, this increase will not affect the curve as it is extended to the right. But if the water, as it filters downward, should reach a plane of less permeable materials, this curve would be further depressed as it is extended to the right.

*Comparing Infiltration Capacities with Infiltration Disposal.* Usually one of our primary objectives in making an infiltration study is to learn what conditions of tillage and soil covers will be required to maintain an infiltration capacity equal to the infiltration disposal capacity. This can now be determined by converting Figs. 2 and 3 to a common base (a time base) and plotting them one over the other as shown in Fig. 4.

From a study of this figure we determine the *R* values of the cover which will be necessary to maintain an infiltration capacity equal to the disposal capacity. In this way we determine if water conservation through increased infiltration can be achieved through improving the infiltration capacity, or if that capacity already exceeds the disposal capacity. In the case of Fig. 4 we find that a cover value of 10.0 will represent almost the maximum cover that will improve infiltration for a single storm on this soil. Before we can decide on cover requirements for a series of storms, we will have to know the surface recovery rates, and the frequency of tillage. It may be assumed that maximum infiltration capacities are re-established at each cultivation.

*Measuring Large Values of Infiltration Capacity under Growing Vegetation.* In all of the above work, where there were vegetative covers on the soil, we were limited in our procedures to measuring infiltration capacities which were less than the profile disposal capacities. These procedures will suffice for most of the practical field work, because in most areas the infiltration capacities will be less than the disposal capacities. But there will be times when it will be desirable to measure infiltration capacities which are higher than the disposal capacities of the profiles. This would be true in areas where we intended to increase the disposal capacity through the installation of tile or through other practices which will improve the profile drainage.

Since the crop covers prevent us taking up the soil to spread over a sand bed, as we did in the experiments shown in Table 1, the alternative seems to be to remove some of the profile materials which restrict rates of disposal and replace these with a well-drained sand that will have a high disposal capacity. This can be done by boring in with a small auger

placed inside a thin-walled pipe which is perforated. The pipe will be forced in at the same rate that the auger bores, about 2 to 3 in below the surface and parallel to it. After the auger is removed, the pipe can be filled with wet sand. The number of sand-filled pipes that will be needed can be determined only through experiment. It will depend somewhat on how much the infiltration capacities exceed disposal capacities, and on how high one wishes to develop the infiltration capacity curves.

Thus far we have considered only the primary factors which affect infiltration. If we measure these accurately and succeed in characterizing and classifying different surfaces and profile conditions which affect infiltration and its disposal, we should then be able to estimate and predict infiltration and disposal capacities of the various field conditions. From these estimates we may also estimate rates at which rainfall in excess of infiltration will accumulate on the surface of a field. This value of accumulated surface water may be designated as $P - F$, where $P$ = precipitation and $F$ = infiltration.

*Scour Erosion and Runoff.* One may deduct surface storage on the field from the accumulated surface water $(P - F)$ to obtain the surface runoff. However, where rill and gully erosion are active, we cannot always depend on surface storage to reduce the runoff. If water is stored in surface depressions and rill and gully erosion drain these depressions later in the storm, the effects of the storage may be to increase rates of runoff. These rills and gullies will also tend to increase velocities of surface flow as it moves down slope, and this too will increase rates of runoff. Thus we see that rill and gully erosion can affect runoff through changing either (1) the amount (inches depth) of water stored on the field surface or (2) the characteristics of the surface flow which affect concentration of the runoff.

The effects of soil erosion on the surface storage factor will usually vary from one field to another, and wide variations occur between various crops and on different land slopes. No measurements were made of the effects of rill and gully erosion on the storage of surface water. However, a number of surface velocities were measured on similar plots, some with gullies and others without gullies. These were made at Coshocton, Ohio, in 1942 and typical results are shown in Tables 5 and 6.

*Effects of Rill and Gully Erosion on Runoff Concentration.* Runoff is affected by a concentration factor which is commonly referred to as a period of concentration. As the period of concentration is decreased, the rates of runoff per unit of watershed area tend to increase. Distance of flow sometimes may be affected by soil erosion, but usually the size and shape of the drainage area will control the distance that water must flow to reach an outlet. But velocity of flow may be greatly affected by erosion which cuts rills and gullies. These rills and gullies in the surface will increase velocities of surface flow as the water moves toward the drainage outlet. Some velocities of surface flow measured in 1942 and 1943 at Coshocton, Ohio, are shown in Table 5. Equipment used in making these measurements consisted of a large water tank mounted on wheels. It could then be hauled to any point on the field to supply water to a plot 6 ft wide and 20 ft long[5].

TABLE 5. COMPARISONS OF SURFACE FLOW VELOCITIES AS AFFECTED BY GULLIES

| Experiment | Condition | Slope | $Q$ per ft of plot width, cfs | Medium velocity, fps | Maximum velocity, fps |
|---|---|---|---|---|---|
| 1 | Wheat stubble, no gullies | 0.06 | 0.12 | 0.70 | 1.0 |
| 2 | Wheat stubble, some gullies | .06 | .12 | 1.33 | 1.5 |
| 3 | Wheat stubble, no gullies | .16 | .12 | .85 | 1.09 |
| 4 | Wheat stubble, gully down middle of plot | .16 | .12 | 1.30 | 2.00 |
| 5 | Bare soil, minor gullies | .06 | .12 | 2.14 | 3.00 |
| 6 | Bare soil, heavy gullies | .06 | .12 | 3.00 | 4.28 |

We can detect a decided effect of crops on velocities of flow by comparing experiment 1 with experiment 5 in Fig. 5, and experiment 2 with experiment 6. The tillage too will affect the velocities of flow, and thereby affect the concentration of runoff. Table 6 lists experiments made in corn fields, three of which were cultivated up and downslope, and three on the contour with a ridge about 4 in high in each corn row. There were no gullies in the plots listed in Table 6 and differences in velocities reflect the effects of different cultivating practices on velocities of surface flow.

TABLE 6. COMPARISONS OF SURFACE FLOW VELOCITIES AS AFFECTED BY CULTIVATION

| Experiment | Condition | Slope | $Q$ per ft of plot width, cfs | Medium velocity, fps | Maximum velocity, fps |
|---|---|---|---|---|---|
| 1 | Contour cultivation | 0.06 | 0.12 | 1.0 | 3.3 |
| 2 | Up and downslope cultivation | .06 | .12 | 3.0 | 4.3 |
| 3 | Contour cultivation | .10 | .12 | 1.4 | 2.0 |
| 4 | Up and downslope cultivation | .10 | .12 | 2.8 | 4.3 |
| 5 | Contour cultivation | .16 | .12 | 1.5 | 3.8 |
| 6 | Up and downslope cultivation | .16 | .12 | 2.6 | 4.6 |

The "up and downslope" cultivation shown in Table 6 produces an effect similar to rilling. It not only increases velocities of surface flow, but it also prohibits significant amounts of surface storage. Both of these will tend to increase the concentration of peak runoff, and to increase quantities as well as rates of runoff.

Rill and gully erosion can practically eliminate the flow-retarding effects of good tillage and cropping practices. Also, we must not overlook the possibility of rills being cut at a time when the rainfall is at a maximum and when all surface basins are filled. When this happens, the sudden release of stored surface water will increase peak runoff. Because of this, we should always consider the water stored in small depressions on cultivated fields as representing a hazard which may increase runoff. On soils that are highly erodible one should be very cautious about impounding large amounts of surface water in small surface depressions on the field. Obviously it will be less hazardous to impound surface waters on soils that are not easily gullied.

## CONCLUSIONS

Soil erosion has a pronounced effect on surface runoff. To evaluate these effects more fully, we shall have to study at least three basic variables of the runoff phenomena. Each of these is a factor of runoff formation and each has a major effect on quantities and rates of runoff; each also is affected by soil erosion. These variables are: (1) rates of accumulation of surface water (equal to precipitation minus infiltration), and affected by splash erosion; (2) surface storage which may be either positive or negative for any short period of time (negative if there is surface storage lost at the time rills are cut), and affected by scour erosion which cuts rills and gullies; and (3) periods of concentration which are affected by distances and velocities of flow, both of which are affected by rill and gully formations.

[5] Some Effects of Raindrops and Surface Flow on Soil Erosion and Infiltration, American Geophysical Union Transactions, vol. 26, no. III, December, 1945.

# Farm Work Simplification—A Joint Problem for Management, Engineering, and Commodity Specialists

By Paul R. Hoff and Ivan R. Bierly
MEMBER A.S.A.E.

THE specialized training that most workers in the several agricultural sciences obtain sometimes makes it difficult for them to gain the necessary perspective to appraise their work objectively. Especially is this true when it comes to finding the proper relationship between workers in a given field and their co-workers in other fields. Perhaps in the earlier days of the development of the agricultural sciences, before such a high degree of specialization was developed, such a perspective was not needed so urgently as at the present time. Now, with more emphasis on the application of results of scientific analysis to farm and other problems, it is important that full advantage be taken of the specialized training and skills of all persons concerned with a given problem. Only in this way is it possible to deal with many problems in the way that they must be met by the farm or other business operator.

This paper is not intended to be an exhaustive treatise on the need for cooperation between the three groups of specialists indicated in the title. It is intended only to summarize some of the conclusions of a management specialist and an engineer after three years of cooperative effort with other subject-matter specialists in work simplification studies of farm jobs. The need for cooperative endeavor in other fields is, however, fully recognized. In fact, it is hoped that these observations may provide not only a logical framework within which work simplification studies may be planned and carried through cooperatively, but also some of the understanding needed for furthering cooperative endeavors in other fields.

Without trying to define the term, for the moment, it appears obvious that work simplification has as its primary objective the easing or shortening of work processes. This is not an end in itself, but simply *one* means of attaining lower unit production cost—the ultimate challenge to management. In appraising the usefulness of work simplification, it is well to keep it in its proper relation to the other means of attaining this desirable end.

Speaking rather generally, there are four principal ways of cutting costs. As applied, for purposes of illustration, to farming, they are:

1 Increasing production per animal and/or per acre, within economic limits. It is well known that very little additional time is required to care for a cow that produces 10,000 lb of milk as compared with one that produces only 5,000 lb, or to grow and harvest 3 tons of hay from an acre of land as compared with one ton. Certainly with the higher production rates, within economic limits, there is a much better chance for a lower cost per unit of product, as well as a lower requirement of labor. Improved equipment or processes may assist in obtaining this objective.

2 Increasing the size of the farm business, again within economic limits. Not much additional time is required to do some of the routine jobs for a large-sized unit than a small one. Ordinarily more is accomplished per man on the larger units, with lower unit costs.

3 Selecting and combining the most profitable enterprises for each farm. In a given area, certain enterprises ordinarily pay better than others, and in a broad sense it is a more efficient use of labor and of other production resources to produce those things which the natural and economic environment favor.

4 Finding and making use of all possible ways to save labor, which is and probably will continue for some time to be a high-cost item in this country. In most cases a farm merely provides a job for the operator and his family—and some hired help, if it will return more than its cost. How good the job is depends on the amount of output per man. A saving in labor in the performance of a given job makes time available either for other productive work, or for additional leisure. The accomplishment of more productive work by the same labor force usually reduces unit costs and increase net profits. On the other hand, a reduction in the length of the workday may be very important in many instances in getting and keeping good-quality help in the years ahead. While the foregoing three factors have the effect of increasing gross as well as net income, this one aims directly at cutting unit costs. Of course, on some farms, a reduction in labor requirements may be necessary before an expansion can be made in the volume of business.

Farm work simplification calls for the three-way cooperation of management, engineering, and commodity specialists

The point of the preceding outline is simply that, so far as individual farm or other business operators are concerned, work simplification provides only one, though a very important one, of several means to lower unit costs. *All* means must be recognized and emphasized in assisting farmers or others in dealing with this problem. In any one situation some other factor than easier and shorter work processes may be of paramount importance.

To the individual who is faced with the problem of cutting unit costs, it matters little whether sug-

This paper was presented at a meeting of the American Farm Economic Association at Philadelphia, Pa., December, 1946.

PAUL R. HOFF is extension associate professor of agricultural engineering and IVAN R. BIERLY is associate professor of farm management, Cornell University, Ithaca, N. Y.

gestions come from management, engineering, commodity specialists, or someone else. If all persons who have an interest in the problem fully understand their place in helping their clients to find the right answers, the cooperative spirit and enthusiasm which such cooperation can develop will help to sell the program to many more people than if each individual permits himself only to see and consider those phases of the problem that fall within his rather narrow sphere of training. Worthy of note perhaps is the fact that such fences generally are tolerated only within an academic institution.

With this viewpoint toward the place of work simplification in a well-rounded program aimed at cutting unit costs, we will raise the question, "What is work simplification?" It seems to be in connection with the definition of the field that the basis has arisen for some difference in point of view on the part of management specialists and engineers as to which of these two fields should have the primary responsibility for the development of the field. It is the authors' contention that this should be a joint undertaking, not only of management and engineering specialists, but of these together with the commodity specialists who have an interest in the problem.

Management specialists have frequently defined work simplification in terms of its objectives, namely and briefly, to ease and shorten work processes to the end that effort is minimized and unit costs are reduced. In these terms, it would appear that work simplification falls within the province of the "management specialists". It seems reasonable that management be charged with the ultimate responsibility for defining or laying out problems which need attention and study so that the business may function more smoothly and economically. Further, it is a problem of management to choose between alternative methods or cost factors, and to appraise the merits and demerits of the alternatives that are offered. But perhaps we should pause here to note that in managing a business decisions must also be made on all of the many production, quality, and other problems involved. Not all decisions fall within the usual province of the "management specialist".

## ENGINEERING VIEW OF WORK SIMPLIFICATION

Engineering specialists ordinarily view work simplification as a systematic, scientific appraisal of the use of power*, tools, and materials to do a given job, and classify this work as "methods engineering". In this appraisal, careful studies are made of (1) equipment, (2) arrangement or layout, (3) methods, (4) organization of work, and occasionally of (5) the forms of the raw material and of the finished product. Certainly anyone who has been trained to make a scientific and systematic analysis of work processes, whether he is a management, engineering, commodity specialist, or someone else, can appraise methods and organization of work, and offer some suggestions for consideration. But it seems equally clear that in studies of equipment and arrangement, either the management or commodity specialist would find himself, in most cases, quite inadequately prepared. Especially would this be true if he should attempt the design of new equipment or a careful check on adjustment or operating efficiency of a piece of equipment, or even more than rather simple changes in the arrangement of the workplace. Not many management or commodity specialists could have designed a milking machine; nor are they much better prepared by training to answer the structural problems involved in rearranging a dairy stable. Certainly the responsibilities involved here are those of an engineer.

Another set of guideposts or standards is needed before the engineering function can be performed. This set of standards must be supplied by the commodity specialist. He can appraise alternatives in terms of the quality of the product that each produces, and can determine whether or not any of the alternatives would have detrimental effects on animals or plants. The management and commodity specialists together can ascertain the proper balance between quality of product, price, and cost per unit to the end that total net returns will be maximized. Then the full team, including management, commodity, and engineering specialists, can test alternatives with these facts in mind.

In the definition of these limits and in testing alternatives, the commodity specialist has a vital interest. A method, organization of work, or change in equipment or arrangement that facilitates the work, promotes its timeliness, and helps to do a better production job, is of just as much interest to him as to the other specialists. Further, as a part of this team, he becomes not only a participant in finding the solution, but in selling the idea of its use as well.

So far, the need for joint assumption of the responsibilities involved in work simplification studies has been outlined in general terms. Perhaps reference again to the viewpoint which a business manager must take will be the best way to summarize the responsibilities of each in this joint undertaking. In developing and then appraising alternatives, there are three primary questions:

## LARGELY WITHIN THE ENGINEER'S PROVINCE

1 Is there another method, organization of work, arrangement, or kind of equipment that should be considered? Finding this means of using power and material to do a better job lies largely within the province of the engineer. But this should not be interpreted to preclude management or commodity specialists from questioning existing methods, arrangement, organization of work, or equipment, nor to applying time and motion study techniques in the evaluation of the various alternatives, nor to offering suggestions for improvements in methods and organization of work based on these observations.

2 Will the new method, equipment, organization of work or arrangement cut unit costs? Finding the answer to this question appears largely to be within the field of the management specialist. Management specialists are concerned with the organization of resources, and the operation of the business in such manner as to provide the greatest continuous profit over a period of time. Keeping unit costs at a minimum is the greatest challenge. One of the most important responsibilities of management is to appraise the alternatives in terms of labor-saving or cost-cutting opportunity. In fact, in the authors' opinion almost all of the work so far done by management specialists in the field of work simplification falls either in this category, or in the field of helping to find ways to fit previously developed innovations into the business operation. To do these things, time-and-motion or travel studies, or surveys may be used as a means of obtaining the necessary procedures or measures of results, depending some on the type of problem under consideration. The fulfillment of the responsibility of developing new equipment and/or structures where needed is the responsibility of engineers. This properly comes under the heading referred to above of methods engineering. The development of new methods to utilize fully the new equipment and/or structures requires the cooperation of all three groups.

Every change that results from engineering research has an impact on management, and may require changes in organization or operation. But it is obvious that economic limits cannot well be set unless the physical limits are at the same time determined.

3 Will the change maintain the proper quality of the product for use or sale, and/or *(Continued on page 253)*

*From an engineering viewpoint, power may be supplied by human, mechanical, or other sources.

# The Use of Heated Air for Hay Curing

By H. D. Bruhn
MEMBER A.S.A.E.

THREE years of observations of barn hay-curing installations in Wisconsin indicate that regardless of whether hay is completely cured in the field or partially cured in the field and "finished" in the mow with unheated air, "good hay weather" is required to produce a high-grade product. Although barn hay curing has advantages of reducing leaf loss in the field, reducing dust and leaf shattering due to field chopping and pneumatic conveying, and reducing bleaching in the field by dew and rain, nevertheless barn hay curing with unheated air has not overcome difficulties encountered due to prolonged periods of cool, humid weather. In these prolonged periods of unsatisfactory drying weather the tendency of the farmer who had hay "down" has been to put it in the barn and start the drier, because he thought the hay would spoil in the field and maybe the drier would save it. If there was any quantity of this wet hay and the damp cool weather continued for several days or more, the hay usually became moldy in the mow. During the early stages conditions in partially cured hay in a barn drier are very favorable for mold growth. The 30 to 40 per cent of moisture, the 70 to 80 F temperature, and the adequate supply of oxygen are ideal conditions for mold growth.

Where waste heat can be utilized to bring about an increase in temperature of the drying air (with engine-operated fans), its use is always economical. Where supplemental heat is supplied from a separate source, its use during "good drying weather" might be questioned from an economic standpoint. However, Wisconsin weather conditions are usually such that additional heat at night is desirable.

Field observations have indicated that, by increasing the air temperature approximately 10 to 12 F with the usual rates of air flow, drying progressed satisfactorily in weather where practically no drying would have taken place with unheated air.

In installations with the usual rates of air flow and with good drying weather, the use of heated air has brought about a decided reduction in drying time. Furthermore, other systems using heated air have been operated very successfully with as little as 8½ cu ft per min per sq ft of mow area.

A very brief summary of a series of drying studies carried on at the Wisconsin Agricultural Experiment Station this past year demonstrates these principles.

Seven feet of chopped mixed hay of 32.3 per cent moisture content was put on a drier. This drier was in a silo so there was no chance for air losses at the sides. The rate of air flow was 12 to 12½ cfm per sq ft with an 11 F temperature increase by supplemental heat. Drying was complete in 86 hr. During this time the outside air averaged a relative humidity of 76 per cent for 60 hr, and there was one thunderstorm of sufficient intensity to cause a short power failure. Actually the relative humidity of the outside air was higher than that of the air leaving the hay for a period of 6 hr.

Another 8 ft of chopped hay with a moisture content of 40.3 per cent was placed above the dried hay. This hay was practically dry by the third day and dry enough for storage by the fourth day. The rate of air flow was 9 to 9½ cfm per sq ft. The average relative humidity of the outside air during this drying was 50 per cent, and with a 12 F temperature rise by supplemental heat, the air entering the hay was at approximately 41 per cent relative humidity.

When the drying of the second layer was complete, a third batch 10 ft deep was added. The first and second fillings had dried, shrunk, and been compressed to the point where the total depth was slightly over 19 ft on the completion of the third filling. This last batch of hay was dried in four days using 8½ to 9 cfm per sq ft of air with the temperature raised 12 F by supplemental heat.

One inch static pressure was required to bring about this air flow. The total mass of hay settled to approximately 16 ft with a density of 6 lb per cu ft.

Besides making it possible to barn-cure hay in damp, cool weather, the use of heated air to speed up drying or reduce the air requirements is of considerable importance to Wisconsin farmers because of the following conditions:

1 Three-phase electric power service is available to only a very few farms.

2 There is a tendency to discourage the use of single-phase motors larger than 5 or 7½ hp for relatively short-period service.

3 Wisconsin barns are usually large.

4 It is generally necessary to fill the haymows to a depth of 14 to 20 ft.

5 Haying should be completed in a period of 10 days to 3 weeks.

Under these conditions the power available is insufficient to force the required amount of air through the hay at hand at the resistance pressures developed to bring about drying in the total mow area in the limited time.

The alternatives are as follows:

1 Chopping the hay with a longer cut to reduce the pressure requirement and thereby make possible a greater flow of air with a given fan and power unit.

2 Building driers for only a portion of the mow and hay. If barn drying a portion of the hay is profitable, then systems should be built that can dry it all.

3 Extending the haying season. This is impractical unless other crops or practices are adopted.

4 The use of engine-driven fans. Engines in the range of 10 to 30 hp are easily adaptable and may prove to be quite popular. Their use will increase the rate of drying because more power is available to move air, and waste heat can be utilized to warm the air entering the hay.

5 The use of supplemental heat, while the equipment will be an added expense, appears to be the only sure way of getting good hay regardless of the weather.

Before the war domestic oil-burning furnaces with a heating capacity sufficient to increase the air temperature of 20,000 cfm by 10 F were selling about one to one and one-half times the list price of fans with this capacity at 1-in static pressure.

Assuming that the cost of a barn-drying system is equally divided into the cost of the fan, the motor and controls, the lumber for the duct system, and the labor of installation, the furnace probably would increase the total cost 25 or 30 per cent. If this additional investment would give a 30 per cent reduction in drying time, enough more hay would be handled to make it a profitable investment.

---

This paper was presented at the Third Barn Hay-Curing Conference sponsored by the American Society of Agricultural Engineers at Chicago, Ill., December, 1946.

H. D. BRUHN is associate professor of agricultural engineering, University of Wisconsin, Madison.

AUTHOR'S NOTE: Acknowledgment is made of the invaluable assistance rendered in the accumulation and compilation of data presented in this paper by the following senior students at the University of Wisconsin: Russell Kilpatrick, Neil Summers, Robert Witt, William Johnson, and Harold McKnight.

Only limited information on equilibrium conditions of moisture content of air and hay are available. However, field observations tend to show that relative humidity of air leaving a mass of damp hay is seldom greater than 90 per cent, or less than 80 per cent during the major portion of the drying time. An average of 85 per cent is probably a fair value.

Some heat of course is generated in the mass of hay itself. It seems reasonable to assume that there will be less heat generated by decomposition of the hay if drying is rather rapid, and there are undoubtedly other sources of heat that are cheaper than hay. Therefore, it would be well to substitute the cheaper source of heat and dry the hay as fast as is economically possible.

If the heat generated in the hay and the heat necessary to increase the temperature of hay are disregarded, the passage of the drying air through a mass of hay can be regarded, with a reasonable degree of accuracy, as an adiabatic process. That is, the total heat of the air passing through the hay remains the same. Under these conditions the wet-bulb temperature of the air will be the same on leaving the hay as on entering. The dry-bulb temperature of the air leaving the hay will be lower than on entering, and this drop in dry-bulb temperature will, of course, be compensated for by the moisture removed from the hay and carried by the air leaving the hay.

Therefore, if the wet-and-dry-bulb temperatures of the air entering the hay are known, it is possible to predict with reasonable accuracy that the air on leaving the hay will have the same wet-bulb temperature and the relative humidity will be about 85 per cent.

Considering the following rather unsatisfactory weather conditions prevailing at Madison, Wis., at 9:00 a.m., June 15, 1946

Wet-bulb temperature, 58 F
Dry-bulb temperature, 64 F
70 per cent relative humidity
62 grains of moisture per pound of dry air.

After this air passes through a mass of damp hay, the following conditions will prevail:

Wet-bulb temperature, 58 F
Dry-bulb temperature, 61 F
85 per cent relative humidity
68 grains of moisture per pound of dry air.

Therefore, each pound of dry air passing through the hay removes 68 minus 62, or 6 grains of moisture.

If the air entering the hay had been previously heated from the dry-bulb temperature of 64 F to a temperature of 72 F, the conditions would have been as follows:

Wet-bulb temperature, 61 F
Dry-bulb temperature, 72 F
52 per cent relative humidity
62 grains of moisture per pound of dry air.

The air after passing through the hay then would be as follows:

Wet-bulb temperature, 61 F
Dry-bulb temperature, 64 F
85 per cent relative humidity
75½ grains of moisture per pound of dry air.

The moisture removed would then be 75½ minus 62, or 13½ grains per pound of dry air.

The heat required to increase the air temperature from 64 to 72 F can be calculated or read directly from an enthalpy table. It is 2.01 Btu per lb of dry air. Therefore, for 2.01 Btu of supplemental heat an additional 7½ grains of moisture can be removed by every pound of air passing through the hay.

If we assume that a 5-hp motor will require 4.9 kw to operate a fan delivering 20,000 cfm, at a charge of 3c per kw-hr, it will cost $1.90 per ton to dry hay from a 40 to 10 per cent moisture content if unheated air is used.

If, however, heated air is used, heat being obtained from a furnace 75 per cent efficient when burning 8c per gal fuel, 7.25 lb per gal, 19,700 Btu per lb, the total cost of electric energy plus fuel for drying the same hay would be $1.63.

With better natural drying conditions it would be more economical to dry without supplemental heat; however, the conditions set up for the previous calculations are fairly representative for rainy spells and the hours of darkness.

Figs. 1 and 2 are examples of weather conditions and moisture-carrying capacity of the air for two periods, namely, June 15 and 16, 1946, and July 2 and 3, 1946, at Madison, Wis.

In the experimental installation on which the data shown in Figs. 1 and 2 were taken, the natural outside air passed through the fan, and was heated on traveling from the fan to the plenum chamber. The air passed directly from the plenum chamber to the hay. Relative humidities are recorded values, and from these values the grains of moisture per pound of dry air were calculated.

The theoretical grains per pound without heat were calculated, assuming an adiabatic process and a relative humidity of 85 per cent for the air leaving the hay. This of course would not hold true in all cases because at times the unheated air was over 85 per cent relative humidity, and without heating it would either leave the hay at a higher humidity or some of its moisture would be left in the dry hay near the bottom of the mow.

Fig. 1 does show, however, that by heating the air there

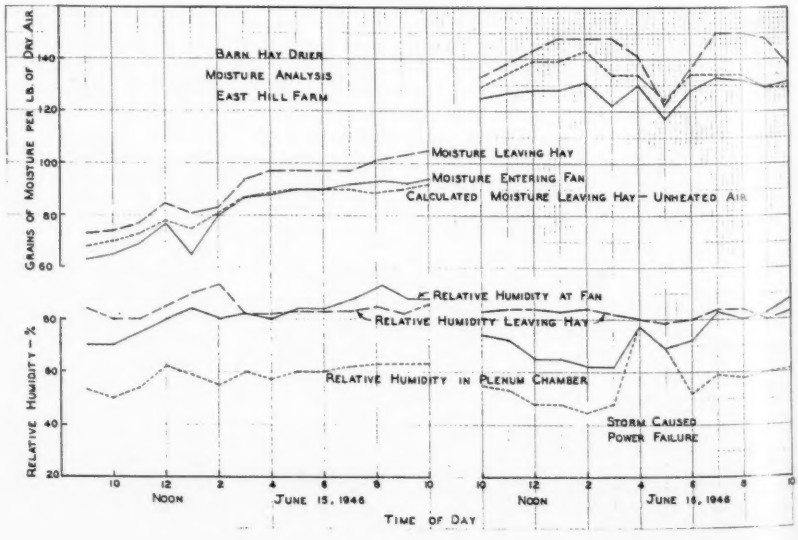



Fig. 1 Very poor drying weather is often experienced during the early portion of the haying season. The curves in this graph indicating the relative humidity and the moisture carried by the air show that under these conditions very little if any drying would actually occur unless the air were heated. Heating the air under these conditions can reduce the over-all operating cost

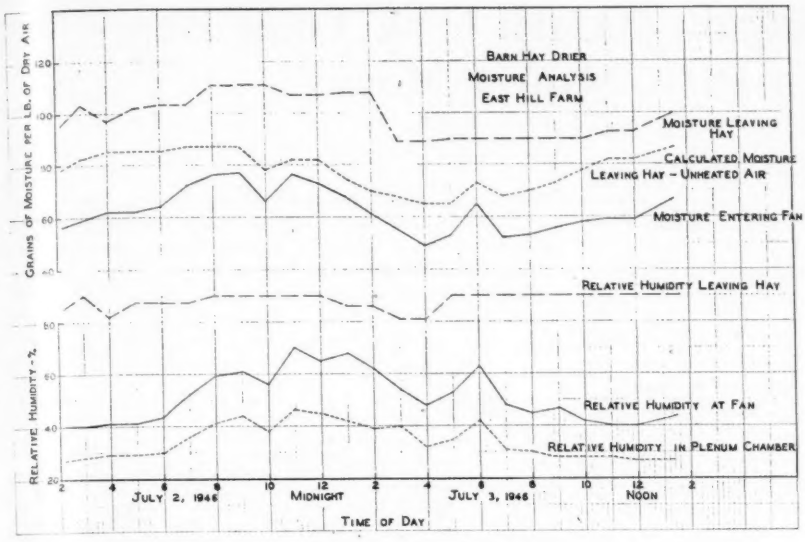



Fig. 2 Later in the haying season much better drying weather is usually encountered. Heating the air under these conditions may increase the total drying cost. However, a much higher rate of drying can be obtained, and the limited drying facilities will not be as great a retarding fact on the rate of hawmaking

was always some drying taking place, while there would have been no drying at times without heating the air, and there might have been a hay-dampening process.

Fig. 2 shows a set of conditions better suited to hay drying. During this period drying would have progressed fairly well without heat both day and night. The only justification for using heated air under these conditions is to increase the rate of drying.

The optimum air temperature increase by supplemental heat has not yet been determined. However, the maximum temperature increase allowable for a given atmospheric condition can be determined from a psychrometric chart with reasonable accuracy. An example follows:

Again consider the weather conditions at Madison on June 15, 1946, at 9:00 a.m.: Dry-bulb, 64F; wet-bulb, 58F; 70 per cent relative humidity. If this air is heated (at constant moisture) to a dry-bulb temperature of 85F, wet-bulb, 66F, and is then passed through the damp hay adiabatically (let us assume), the air is likely to emerge at a wet-bulb temperature of about 66F and at 85 per cent relative humidity. The air under these conditions will have a dew point of 64F which will be just on the borderline of precipitation if the air in the haymow above the hay is the same temperature as the outside air. Heating the incoming air over 21F in this case would cause precipitation or a wetting of the top few inches of the hay in the mow. In cases where precipitation has actually occurred, droplets of water can be seen hanging from the individual hay stems.

The dry-bulb temperature of this air on leaving the hay would probably be about 69F and as this emerging air warms the mow space, the amount of temperature rise of the air entering the hay can be progressively increased until the air temperature above the hay becomes stabilized.

Heat generated within the hay itself will decrease the allowable temperature increase of the drying air. The amount of this decrease will depend to a considerable extent upon the rate of airflow. At high rates of airflow the heat generated in the hay will probably be of no consequence; however, at very low rates of airflow the heat generated in the hay can easily be of sufficient quantity to make heating of the incoming air entirely undesirable. This situation is admirably demonstrated by the warm, wet spots which often develop on top of the hay when rather damp field-dried long or chopped hay is put in a mow to considerable depth and where no barn drier is used. Here the rate of airflow is practically zero and considerable heat is developed in the hay itself. As the warm, damp, slow-moving air approaches the surface of the hay, its temperature drops below the dew point and precipitation occurs.

In barn-curing installations the entire top surface of a mow sometimes becomes wet when considerable quantities of very wet, short-cut clover hay are put in a drier and the airflow, for one reason or another, is very low or entirely absent.

With high rates of airflow the heat generated by the hay is carried off with relatively little increase in air temperature. Therefore, until more experimental data are available, it will be wise to use rather high rates of airflow if the air entering the hay is being heated to any appreciable extent. This will bring about quick drying and prevent the moisture removed from the hay at lower depths from being deposited on the top few inches of the hay.

## Farm Work Simplification

*(Continued from page 250)*

maintain animals or plants at effective production levels? Neither the engineer in a study of the application of power and materials, nor the management specialist in the appraisal of the change from an economic viewpoint, are fully prepared to answer this question. It is up to the animal husbandry specialist to specify the width of stalls that should be put into a new dairy stable; or the fruit specialist to ascertain the degree of injury in an orchard where a new spraying practice or sprayer is being tried; or to the poultry specialist to ascertain the change in quality that has taken place within an egg.

Finally and perhaps most elementary of all in an appraisal of the joint responsibilities of the three specialists in examining work processes is the fact that *the business manager must answer all of these questions at the same time.* The problem of the manager in considering changes is to find that balance or combination between the several factors with which he works that will minimize labor requirements and costs, but still maintain quality and biological productive capacity. The best answer from a strictly engineering viewpoint might be an entirely automatic system; but this might not be the most economical; or it might not result in the necessary quality of product. On the other hand, in view of great economies due to some new device, method, or arrangement, some sacrifice in quality might be justified.

Management, engineering, and commodity specialists can make the largest contribution to the field of work simplification by each developing his own subject matter and relying on the other members of the team for the contributions they can make best. There must, however, be a team in which each person is not only qualified in his own field, but ready and willing to appreciate the problems of the other members and to work jointly toward a solution.

# Air Distribution through Long, Loose Hay in High, Narrow Mows

By J. B. Stere and L. S. Singley
MEMBER A.S.A.E. MEMBER A.S.A.E.

THE size and shape of haymows is the principal factor limiting the performance of mow hay finishers in Pennsylvania. This limiting factor is further influenced by the quality of hay to be cured and the rate of filling a mow. Haymows in the typical bank-type barn in Pennsylvania are usually about 20 by 40 ft and from 18 to 30 ft high. The number of mows in a particular barn varies from two to five, but the size and shape of each mow is fairly consistent. In most cases, each mow is filled separately with different cuttings or with different varieties of hay. Attempts by some to influence farmers to combine mows or change their practices of filling have not been accepted because such suggested changes offered no improvement in farm management.

*Slotted Floor Distribution System.* The slotted, slatted, or false floor system, as shown in Fig. 1, was the first method of air distribution used in these high, narrow mows. This system is satisfactory when hay that is placed in the upper portion of the mow is coarse, mature, and low in moisture content. The development of this method of finishing hay in mows has focused more and more attention from year to year to the value of high-quality hay. The variety of hay and its state of maturity and leafiness not only affect the quality of hay, but these factors also affect resistance to air flow through the hay. The better the hay quality, the greater is its resistance to air penetration.

Six years' experience with the slotted-floor system in high, narrow mows on farms where hay quality has improved from year to year has shown that this system is not effective in satisfactorily penetrating the upper levels of such mows. Air losses through the sides of the mow are excessive and fan performance is impaired because of increased resistance pressures as higher levels of mowing are reached. Static pressures measured approximately 10 ft in front of the fan were frequently found to be as high as 1 in. (All static pressures mentioned in this paper were measured approximately 10 ft in front of the fan.)

Attempts to reduce side losses of air and efforts to direct more air through the center of the mow by closing side laterals, further increased the static pressure as much as 0.2 in. When the static pressure increased from 1 in to 1.2 in, the rated output of the fan (Fig. 3) dropped from 17,400 to 11,000 cfm, or a decrease of 6,400 cfm. This increase in pressure caused by closing the side laterals reduced

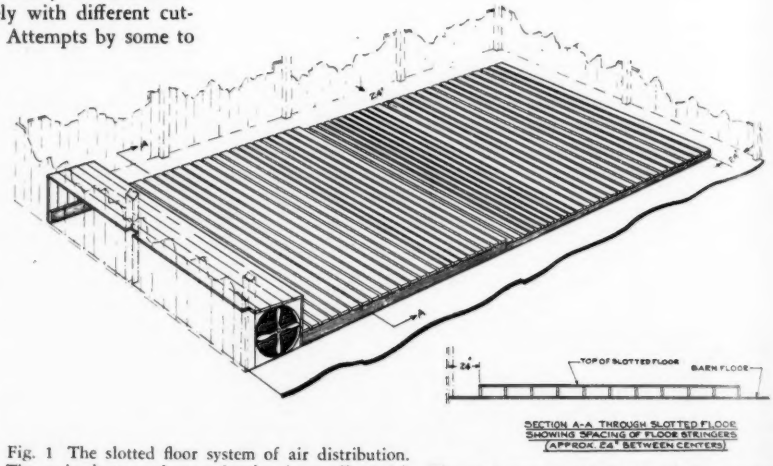

24"
24"
TOP OF SLOTTED FLOOR
BARN FLOOR
SECTION A-A THROUGH SLOTTED FLOOR SHOWING SPACING OF FLOOR STRINGERS (APPROX. 24" BETWEEN CENTERS)

Fig. 1 The slotted floor system of air distribution. The main duct or plenum chamber is usually 4x4 ft. The total cross-sectional area of the openings which feed the slotted floor is generally 80 per cent of the cross-sectional area of the main duct. Slots in the floor where air enters the hay, range from ¾ to 1 in in width

Fig. 2 This is a cross-sectional view of high-quality hay on slotted floor. The relatively short distance from the outside lateral to the edge of the mow, coupled with the bridging effect of hay over the side of the lateral and the lower density of hay in this area, creates easy paths for air to escape. The higher density in the center of the mow and the horizontal "grain" of hay indicate that there is less resistance to air flow in the horizontal direction than in the vertical direction in any mow

This paper was presented at the 3rd Barn Hay-Curing Conference sponsored by the American Society of Agricultural Engineers at Chicago, Ill., December, 1946.

J. B. STERE and L. S. SINGLEY are agricultural engineers, West Penn Power Co.

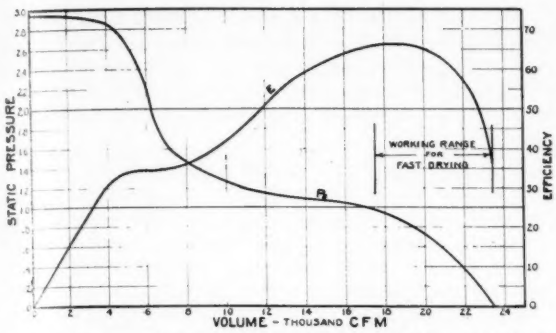



Fig. 3 These are performance curves of the propeller fan, which is the most commonly used type in western Pennsylvania

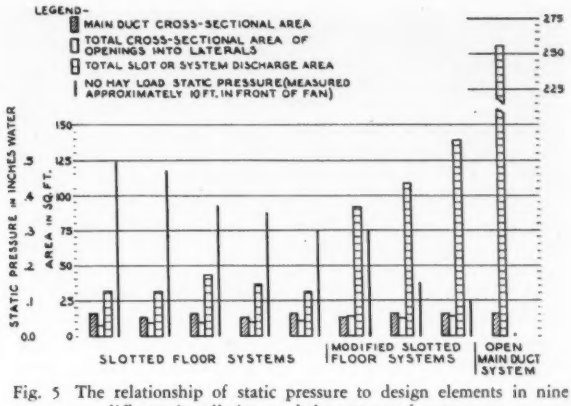

LEGEND-
MAIN DUCT CROSS-SECTIONAL AREA
TOTAL CROSS-SECTIONAL AREA OF OPENINGS INTO LATERALS
TOTAL SLOT OR SYSTEM DISCHARGE AREA
NO HAY LOAD STATIC PRESSURE(MEASURED APPROXIMATELY 10 FT. IN FRONT OF FAN)
STATIC PRESSURE IN INCHES WATER
AREA IN SQ. FT.
SLOTTED FLOOR SYSTEMS
MODIFIED SLOTTED FLOOR SYSTEMS
OPEN MAIN DUCT SYSTEM

Fig. 5 The relationship of static pressure to design elements in nine different installations and three types of systems

the output of the fan to a point where the amount of air penetrating the hay was decreased rather than increased.

*Modified Slotted Floor.* In an effort to reduce the system static pressure, and at the same time minimize side air losses, the following structural changes were made in twelve different slotted floor installations: (1) One lateral on each side was removed; thus the outside laterals were then 4 ft from the edge of the mow. The remaining laterals were shortened in length so that they ended 4 ft from the end of the mow. Previously these distances were 2 ft. (2) The height of center laterals were increased so that the total cross-sectional area opening into these laterals was equal to or slightly greater than the openings for the slotted floor before this alteration. (3) The floor slots were increased in width to 3 in and sometimes to 4 in (Fig. 4).

The modified slotted floor system was found to have practically the same limitations as the original slotted floor. "No-hay-load" system pressures, however, were generally lower. When hay was placed on each system, static pressures increased rapidly, side losses were still excessive, and upper

Fig. 4 Two views of modified slotted floors

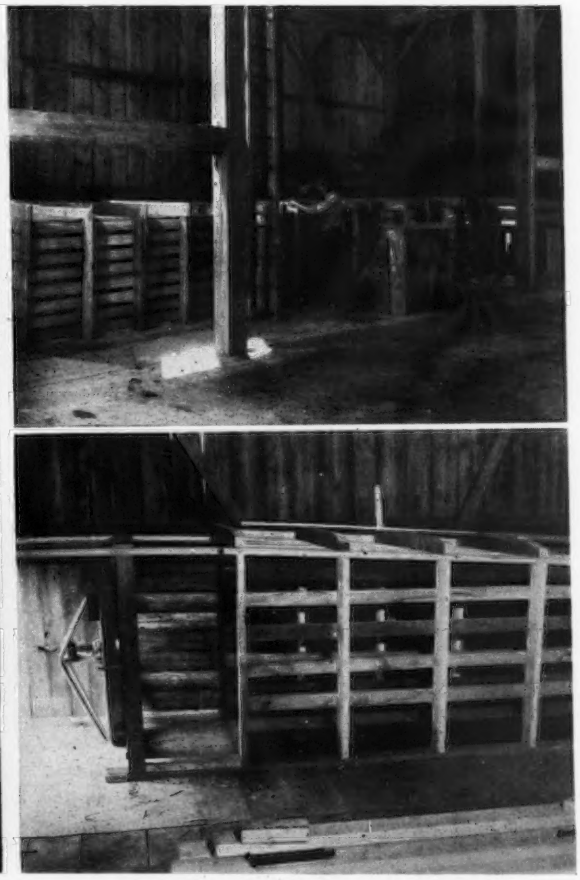


Fig. 6 Two views of the slotted main duct systems

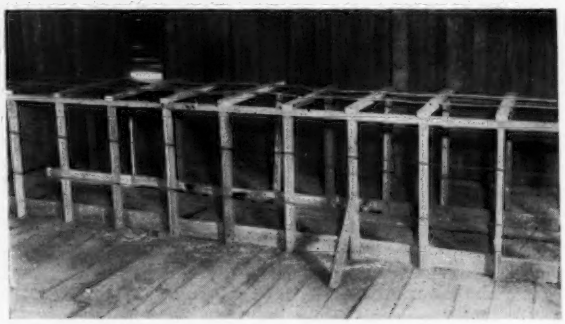


Fig. 7 A view of the open main duct

levels of good quality hay again were not satisfactorily penetrated.

A study of pressures without hay on these systems revealed three things that were largely responsible for resistance pressures, namely, (1) size of the main duct, (2) size of the opening into the laterals, and (3) slot area where air entered the hay. The relationship of static pressure to these three design elements in nine different installations and three types of systems is shown in Fig. 5.

In order to utilize fully the static pressure that the fan is capable of working against, to force sufficient air through the hay, it was necessary to reduce the resistance of the system to a point where uniformity of air distribution through the hay would not be impaired.

In any system a widening of the slots slightly decreases the no-load system static pressure. Beyond a certain width, however, this has no influence and a complete removal of slats has no further effect.

In one system where the main duct, 15 ft in length, was not altered throughout the test, but the slot and lateral openings were changed, the following tabulated system pressures were found:

| Main duct area, sq ft | Entrance lateral area, sq ft | Slot size, in | Slot area, sq ft | Static pressure, in |
|---|---|---|---|---|
| 13.75 | 8.9 | 1 | 31.2 | 0.47 |
| 13.75 | 8.9 | 1 and 4 | 89.8 | 0.47 |
| 13.75 | 8.9 | Removed slats | | 0.47 |
| 13.75 | 14.4 | " " | | 0.23 |
| 13.75 | 16.7 | " " | | 0.15 |
| 13.75 | 14.4 | 3.75 | 92.2 | 0.30 |

*Slotted Main Duct, No Laterals.* A slotted main duct system (Fig. 6) was designed without laterals to discharge air directly into the hay for the purpose of obtaining fast drying in high narrow mows. Studies of this system indicated that little system resistance was required to secure uniform air distribution.

This system performed satisfactorily when the height of good quality hay did not exceed 12 ft. The drying time up to this level was as low as four days. Greatest side air losses were found to be around 18 in to 2 ft above the floor. By closing the sides of the main duct to reduce these side losses, and thus secure greater vertical penetration, the static pressure of the system was increased, which reduced the output of the fan. In one instance, the effective height at which fast drying could be accomplished was actually reduced when the sides were closed.

*Open Main Duct, No Laterals.* After the resistance of the distribution system was minimized, the resistance where air entered the hay became a problem. In an effort to reduce this resistance, the slats on the duct were eliminated and two lengths of ⅜-in stranded steel cable were evenly spaced on each of the sides and top of the duct frame work to support the hay (Fig. 7).

In the open main duct system shown in Fig 7, the no-load static pressure was zero. Static pressures at various depths of hay were as follows:

| Depth of hay, ft | Static pressure, in |
|---|---|
| 5 | 0.10 |
| 8 | 0.15 |
| 13 | 0.175 |
| 17 | 0.20 |
| 20 | 0.225 |

To decrease excessive side losses in this mow with 20 ft of hay, the sides of the duct were closed. While this reduced side losses, there was no noticeable increase in vertical penetration. This closing off of part of the discharge area actually decreased fan output because the static pressure was increased from 0.225 to 0.55 in. Experiences with the open main duct system revealed that satisfactory penetration was obtained on the sides and to heights of 12 ft.

From these experiences and studies, it has been concluded that in order to secure adequate vertical penetration for fast drying of good quality hay in high narrow mows, it will be necessary to develop other means for directing air through hay. Studies will be conducted this year of several contemplated plans for improving the performance of hay finishers in high narrow mows.

Fig. 8 *(Left)* A view of an early distribution system used in high, narrow mows for chopped hay. Maximum static pressure reached, 4.2 in. *(Right)* The same system, as at left, in revised form. Maximum static pressures were reduced to 2 in by opening the system discharge areas

# Curing Baled Hay

By C. K. Shedd and E. L. Barger
FELLOW A.S.A.E. MEMBER A.S.A.E.

OBSERVATIONS on barn curing of several lots of baled hay were made at Iowa State College in 1945 and 1946. This work was a cooperative project between the Iowa Agricultural Experiment Station and the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

All of the hay on which these observations were made was baled from the windrow by a pickup automatic twine-tie baler. Size of bales was 14x18x35 - 40 in. The weight of bales when containing between 25 and 30 per cent moisture was generally between 55 and 65 lb, about 11 lb per cu ft.

The first lot of baled hay was cured in the swine farm barn in August, 1945. This barn was equipped with a Louden prefabricated metal duct system with tapered ducts as shown in Fig. 1. Air was supplied by an engine-driven, axial-flow fan rated to deliver about 14,000 cfm, or 20 cfm per sq ft of floor. Air flow was not measured. This lot of hay was second-cutting alfalfa containing an average of 24.5 per cent moisture. Bales were laid on edge with spacing of about 2 in between bales. Each layer of bales was laid crossways of the layer below. The barn was filled to a depth of six layers of bales, or about 9 ft.

The fan was operated 71.6 hr to finish curing. The hay was cured without any heat or mold damage and was of good color and quality with most of the leaves retained. While this hay was not very high in moisture content, it was thought that some damage would have resulted if it had been placed in a barn without forced ventilation. The principal advantages of barn curing were as follows: (1) More leaves were retained than if the hay had been fully cured in the field, and (2) baling could be started earlier in the day, thus permitting a longer working day for the crew.

In 1946 one lot of baled hay was cured in the swine farm barn and two lots in the horse barn. The lot cured in the swine farm barn had about the same initial moisture content and cured to about the same quality as in the 1945 test.

This paper was presented at the 3rd Barn Hay-Curing Conference sponsored by the American Society of Agricultural Engineers, at Chicago, Ill., December, 1946. Approved for publication as Journal Paper No. J-1419, Project No. 922, Iowa Agricultural Experiment Station.

C. K. SHEDD is agricultural engineer (BPISAE), U. S. Department of Agriculture, and E. L. BARGER is professor of agricultural engineering, Iowa State College.

The horse barn was equipped with a Louden prefabricated metal duct system as shown in Fig. 2. Air was supplied by a 48-in, axial-flow fan driven by a 7.5-hp electric motor which supplied about 15 cfm per sq ft of floor.

The first lot of baled hay cured in the horse barn was 31 tons of first-cutting alfalfa containing about 25 per cent moisture in the lower part and 21 per cent moisture in the upper part of the hay as placed in the barn. The haymow was filled on June 22 to 24, 1946, to a depth of five layers of bales or about 7.5 ft, using the same method of stacking bales as explained above.

The fan was operated 150 hr. The hay was cured to about 12 per cent moisture and was green and leafy with no heat or mold damage.

The second lot cured in this barn was second cutting containing between 25 and 30 per cent moisture. The haymow was filled on August 8 to a depth of about 7 ft. The bales were not carefully stacked as in previous tests. Bales in the central part of the haymow were left where they were dropped by the fork. Only enough hand work was done to keep the surface of the pile of bales approximately level. The fan was operated 136 hr. The bulk of this hay cured to good quality, but there were a number of bales in top layers that developed temperatures above 100 F. Bales observed to be heating were opened and spread out and then cured without further heating. This hay did not cure to uniform moisture content in the field because of uneven thickness of swath and size of windrows in different parts of the field. The bales that developed high temperatures no doubt had higher than average moisture content.

Two lots of hay were cured in a drying bin in the agricultural engineering laboratory where more detailed observations were made than in the barns. This bin is 7 ft, 3 in square and 12 ft high above the false floor. The false floor is made of 1x4-in boards set on edge and spaced ¾ in apart. A plenum chamber under the false floor is 2 ft deep.

Bales were stacked in this bin by the same method as described above for the first lot in the swine farm barn. There were ten bales in each layer. Thermocouples for measuring temperature were placed in the centers of two bales in each layer and these bales were weighed when placed in the bin and weighed and sampled when removed.

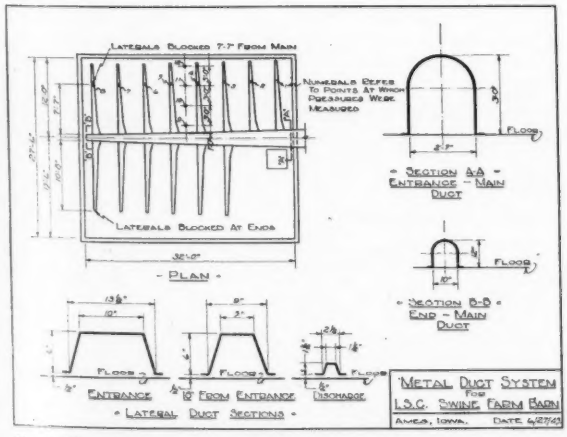

LATERALS BLOCKED 7-7" FROM MAIN
NUMERALS REFER TO POINTS AT WHICH PRESSURES WERE MEASURED
LATERALS BLOCKED AT ENDS
- PLAN -
- SECTION A-A - ENTRANCE - MAIN DUCT
- SECTION B-B - END - MAIN DUCT
ENTRANCE
½ FROM ENTRANCE
DISCHARGE
- LATERAL DUCT SECTIONS -
METAL DUCT SYSTEM FOR I.S.C. SWINE FARM BARN
AMES, IOWA. DATE 6/27/45

Fig. 1 Plan and section views of Louden prefabricated metal duct system used in Iowa State College baled hay curing observations

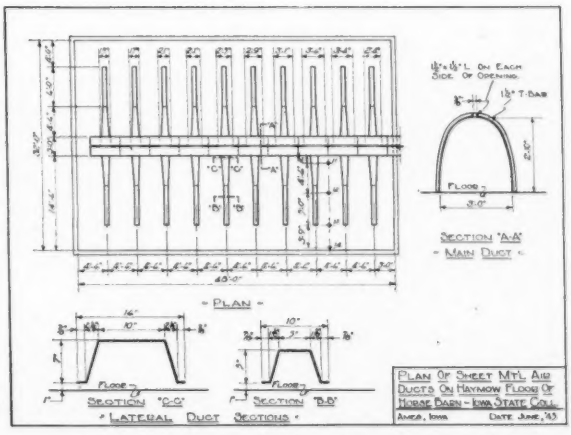

- PLAN -
SECTION "A-A" - MAIN DUCT -
SECTION "C-C"
SECTION "B-B"
- LATERAL DUCT SECTIONS -
PLAN OF SHEET MTL AIR DUCTS ON HAYMOW FLOOR OF HORSE BARN - IOWA STATE COL.
AMES, IOWA DATE JUNE, '43

Fig. 2 Views of duct system similar to that in Fig. 1 used in Iowa baled hay curing studies

The first lot of baled hay cured in this bin was mixed red clover-timothy-sweet clover hay baled and placed in the bin on July 10, 1946.

Temperatures in the centers of bales immediately after filling the bin ranged from 82 to 104 F and remained close to this range during the following day when the fan was not operated. The fan was started on the morning of July 12 and operated continuously for 94.75 hr. After the fan was started, temperatures in the centers of bales dropped below entering air temperature within 30 min. In the first part of the drying period, temperatures in bales in the bottom layer were about 10 deg below and in the top layer about 3 deg below entering air temperature. Near the end of the drying period, temperatures in the bottom layer were the same as entering air temperture and in the top layer, 5 deg lower.

Hay was removed from this bin on July 16. All bales cured without heat or mold damage. Data on bales in the top and bottom layers are given in Table 1.

TABLE 1. WEIGHTS AND MOISTURE CONTENTS OF MIXED CLOVER-TIMOTHY HAY CURED IN DRYING BIN
JULY 10 TO 16, 1946

| Bale | Layer | Weight, lb | | Moisture, per cent | |
|---|---|---|---|---|---|
| | | Initial | Final | Final | Calculated initial |
| 1 | Bottom | 59.53 | 51.86 | 8.0 | 27.6 |
| 2 | " | 54.68 | 46.75 | 9.6 | 28.4 |
| 11 | Top | 52.70 | 50.99 | 9.5 | 19.8 |
| 12 | " | 56.22 | 53.55 | 11.0 | 22.0 |

The second lot of hay cured in this bin was second cutting alfalfa, baled and placed in the bin on July 18, 1946. Bales were stacked by the same method as before to a depth of seven layers, or about 10.5 ft. The calculated average initial moisture content was 33.3 per cent and the range in different bales from 22.5 to 45.0 per cent. The initial moisture content was calculated from the final moisture content and loss of weight during drying, assuming that weight lost was moisture. Obviously this method of calculation gives higher initial moisture content than actually was present in case of bales where there was any heat or mold damage.

On account of the high moisture content of this lot of hay, a high rate of air flow was used. The rate during the first 88 hr was 29 cfm per sq ft of floor. The rate was increased then to 50 cfm per sq ft of floor because it was evident that bales in the top layers were not curing satisfactorily. It is questionable if the drying rate was improved materially by this high rate of air flow. The fan was operated continuously for the first 134 hr, then from 3 to 7 hr per day, in daytime, for 29 hr.

Temperatures in the centers of bales immediately after filling the bin and before starting the fan were from 106 to 122 F, showing that some heating had started in all bales. One-half hour after starting the fan, temperatures in the centers of bales in the bottom layer had dropped to 92 and 93 F, with entering air temperature of 94 F, but bales in the fifth and sixth layers were still 99 to 120 F. During the early part of the drying period after the first day, temperatures in bales were from 5 to 10 deg below entering air temperature, and there was little difference between temperatures in top and bottom layers. When the fan was turned off over night on July 24, temperatures increased from 68 - 75 F to 101 - 107 F in the fifth and sixth layers, after these bales had been held below 86 F for five days with the fan running.

An observation of rate of temperature drop in bales was made on the morning of July 26 after the fan had been turned off overnight. The temperature in the center of bale No. 11 in the sixth layer was 70 F when the fan was turned off on July 25. The next morning the temperature had increased to 103 F. After starting the fan, the temperature in the center of this bale dropped to 96 F in 10 min, to 89 F in 20 min, to 82 F in 30 min, and to 72 F in 3 hr, when the entering air temperature was 77 F.

Data on individual bales in this lot of hay are recorded in Table 2.

Observations in these studies were not as extensive nor in as much detail as would be desired. The practices carried out in the two barns were designed to produce good hay rather than to produce good experimental results. However, some conclusions are indicated, if not proven.

The method of stacking bales by laying them on edge with 2 or 3 in air space beween them and each layer of bales placed crosswise of the layer below produced satisfactory results with hay under 30 per cent moisture. Some difficulty was experienced in curing hay containing more than 30 per cent moisture, but 30 per cent has not been definitely established as a moisture limit. The limit would no doubt vary with depth of hay.

No measurement was made of the proportion of air going through the bale. It may be assumed that most of the air flow was around rather than through the bales. However, the rapidity of temperature drop in a hot bale when subjected to air flow indicates that drying was effective by diffusion, if not by conduction, through the bale.

Resistance of baled hay to air flow was not studied comprehensively. The static pressures measured under baled hay in the 1946 tests were materially lower than under equivalent depths of loose hay the previous year. For example, in curing the first lot (7.5-ft depth) of baled alfalfa hay in the horse barn in 1946, air pressure of 0.08 in was measured at the floor. In curing 7-ft depth of loose alfalfa hay the previous year, the air pressure at the floor was 0.22 in. Resistance would, of course, depend upon the spacing allowed in stacking the bales.

In 1942, some observations were made of storage without forced ventilation of alfalfa baled at different moisture contents and at different density of bales. Bales were stacked under a shed open on all sides.

Hay baled at normal density of 11 to 12 lb per cu ft and 16 per cent moisture stored without any damage except some loss of green color in solid bulk piles with bales laid either on side or on edge. There must *(Continued on page 260)*

TABLE 2. DATA ON BALED HAY DRIED IN BIN IN AGRICULTURAL ENGINEERING LABORATORY
July 18 to 29, 1946

| Bale No. | Layer | Weight, lb | | Moisture, per cent | Samples, August 27, 1946 | | | Calculated initial moisture, % |
|---|---|---|---|---|---|---|---|---|
| | | 7-18 | 8-27 | | Description | Color | Odor | |
| 1 | 1 | 54.42 | 45.82 | 8.0 | Alfalfa | Bright green | Normal | 22.6 |
| 2 | 1 | 62.56 | 44.36 | 9.0 | " | " " | " | 35.7 |
| 3 | 2 | 56.83 | 46.18 | 9.0 | " | " " | " | 26.0 |
| 4 | 2 | 64.80 | 51.71 | 8.0 | " | " " | " | 26.6 |
| 5 | 3 | 53.34 | 40.51 | 7.5 | " | " " | " | 29.7 |
| 6 | 3 | 56.33 | 41.81 | 9.5 | " | " " | " | 33.0 |
| 7 | 4 | 58.32 | 43.31 | 8.5 | " | " " | " | 31.8 |
| 8 | 4 | 59.88 | 44.15 | 8.5 | " | " " | " | 32.4 |
| 9 | 5 | 66.45 | 48.48 | 9.5 | Alfalfa and ½ grass and alsike | Brown to grey green | Musty | 34.9 |
| 10 | 5 | 70.17 | 44.74 | 9.5 | Alfalfa plus little grass | Brown to grey green | " | 42.2 |
| 11 | 6 | 65.24 | 39.41 | 9.0 | Alfalfa (very dusty) | Light brown to grey green | " | 45.0 |
| 12 | 6 | 62.04 | 40.29 | 7.5 | Alfalfa | Grey green | " | 39.8 |

# Air Flow through Baled Hay

By A. T. Hendrix
MEMBER A.S.A.E.

EFFORTS have been made in widely separated sections of the country to dry tough baled hay by forced ventilation. Some successful results have been reported even when the initial moisture content of the bales was high. It has been considered generally desirable to permit the hay to dry in the field to 30 or 35 per cent moisture content before baling, and then bale the hay as loosely as is consistent with good practice and ease of handling. When placed on a forced ventilation drier, such bales, as well as those of higher moisture content, have been successfully dried for safe storage. It has not been known, however, what factor or factors effected the satisfactory drying of hay in bales. Recent experimental results indicate that the respiratory heat of the hay would partially effect drying of the bale with a minimum volume of air flow through and about the bale to carry away the generated heat and evaporated moisture.

There has been some question as to the possibility of obtaining any appreciable air flow through bales. Some investigators have reported adequate rate of flow to effect drying, but the actual rate of flow through the bale has not been indicated.

*Experimental Equipment and Procedure.* In an effort to measure the rate of air flow through bales, the experimental equipment shown in Fig. 1, and diagrammatically in Fig. 2, was constructed. The fan used for the test was capable of delivering an adequate volume of air at several inches of static pressure. The fan was driven by an electric motor through a variable-speed drive so that any desired static pressure and air flow could be obtained. Inclined manometers were installed, as indicated by Fig. 2, to determine effective pressure drop through the bale, and also to indicate the effective pressure on the discharge orifice, which was a sharp-edged circular orifice four inches in diameter. Volume of air flow through the bale was calculated by orifice formula and was checked by anemometer.

Alfalfa hay, with a small amount of grass, was cut in the early bloom stage. This hay was of short growth and small stems. It was allowed to dry in the field until considered satisfactory for baling, and was then baled by a pickup baler, wire tied, and taken to the laboratory for test the same day as cut. The hay was of 31 per cent moisture content as sampled.

In the laboratory each bale tested was sealed around the outer edges by immersing each edge in melted paraffin and allowing the paraffin to congeal before removing the bale. The bale was then placed in the box, as indicated by Fig. 2, and melted paraffin was poured around the outside of the wax seal, thus eliminating any possibility of air leakage past the outside of the bale. All air discharged from the orifice passed through the exposed net area of the bale.

*Results.* Test results of air flow through baled hay of two densities are indicated by Fig. 3. Rates of air flow are shown both at the start of the test and after the hay had been dried to the moisture content shown. As the hay was dried the overall size of the bale was not changed; therefore, the results indicated would not be the same as would be experienced if bales were subject to compression and size shrinkage as in a stack or mow.

During test it was observed that air flow through a bale when placed in this position relative to air flow was not at all uniform. A considerably greater rate of flow was obtained through one-half the bale than was obtained through the other half. The proportion varied to a considerable extent, depending upon the relative tightness and resultant density of the

This paper was presented at the 3rd Barn Hay-Curing Conference sponsored by the American Society of Agricultural Engineers at Chicago, Ill., December, 1946.

A. T. HENDRIX, agricultural engineering division, Tennessee Valley Authority.

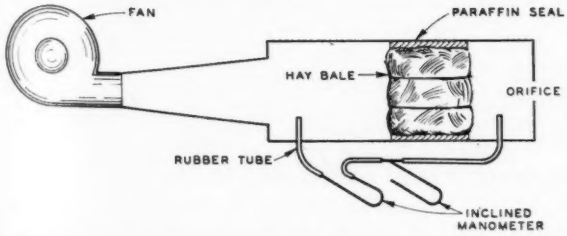



Fig. 1 *(Top)* Experimental installation to measure the rate of air flow through baled hay • Fig. 2 *(Bottom)* Diagrammatical sketch of experimental equipment shown in Fig. 1

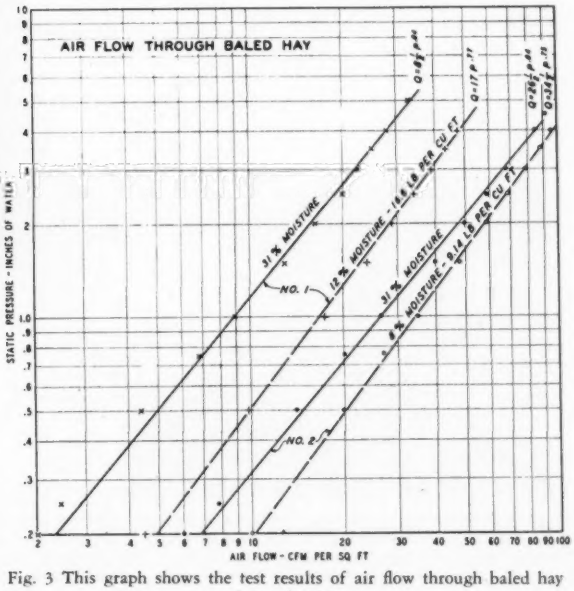

AIR FLOW THROUGH BALED HAY
STATIC PRESSURE - INCHES OF WATER
AIR FLOW - CFM PER SQ FT
31% MOISTURE
12% MOISTURE - 14.8 LB PER CU FT
NO. 1
31% MOISTURE
8% MOISTURE - 9.14 LB PER CU FT
NO. 2

Fig. 3 This graph shows the test results of air flow through baled hay of two densities

different portions of the bale. Under some conditions of field baling considerable variation in density within the bale may be experienced. Because of this variation in density within the bale it was considered desirable to place bales on edge instead of on the side when stacking them in the mow for drying by forced ventilation.

From Fig. 3 it may be noted that, as the hay was dried and consequently decreased in density, the value of $n$ in the equation $Q = CP^n$ tended to change in value toward that previously obtained in air flow through loose hay of lesser density than that of the bales tested.

CONCLUSIONS

An appreciable air flow is effected through baled hay at low static pressure, and the rate of flow is increased as effective pressure is increased in accordance with the general equation of air flow through hay as determined by previous experiments. If not baled too tightly, and if placed properly in the mow, bales should dry satisfactorily by means of available heat of respiration and other sources, together with the drying effect of the actual flow of air through the bale. To reduce losses and mold to a minimum the bales should be dried as rapidly as is economically practical.

## Agricultural Engineering in Comparison

*(Continued from page 231)*

In bachelor's degrees we were slightly above the engineering group average. Other education, presumably experience and individual study, accounted for only 13+ per cent of the agricultural engineers, in contrast to 24+ per cent of all engineers. This suggests recognition of the professional courses in agricultural engineering as generally the logical approach to an agricultural engineering career. The manner of accounting for professional engineering degrees in the tables was not evident.

We are not in a position to say at this time that there is any great personal advantage in being included on the Roster. In another national emergency it might be of considerable advantage to any individual who feels that he would be most useful in any particular specialized field of technical or professional work. It does appear that at present there would be a definite advantage to agricultural engineers as a group in having a larger percentage of the group included, so that the figures might more nearly represent its actual strength and importance.

## Curing Baled Hay

*(Continued from page 258)*

have been some aeration in these solid bulk piles, as shown by the fact that a bale fully wrapped in Sisalkraft became moldy. Also, a bale with the same moisture content but baled at high compression of 16 lb per cu ft became moldy even though it was fully exposed as an individual bale in a ventilated building.

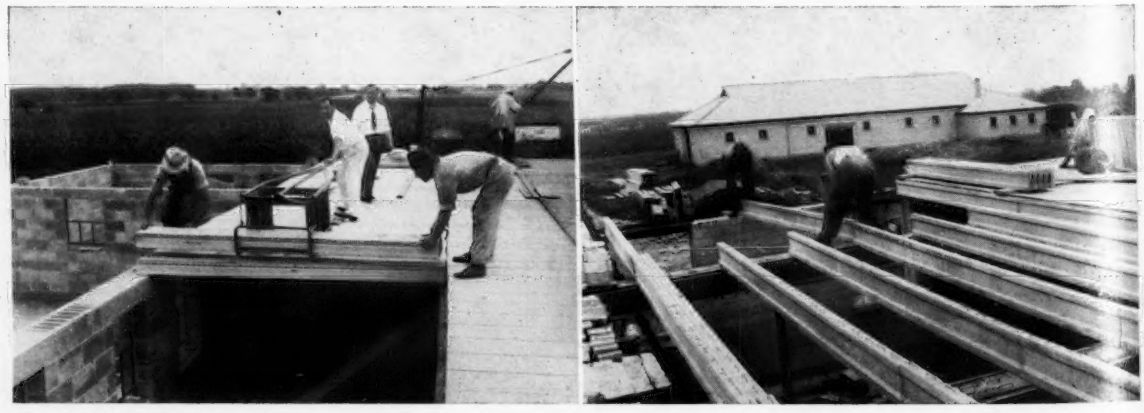
Two small lots were baled with an average of 26.4 per cent moisture. One lot was baled at normal density of 11 to 12 lb per cu ft and the other at high density of 15 to 16 lb per cu ft. Both were stacked with bales laid on side, with about 6 inches space for aeration at edges and ends of bales. Bales of normal density cured satisfactorily but bales of high density became moldy.

There were no unusual storms nor any protracted periods of cloudy weather during any of the periods when these observations were made on curing baled hay. In 1942 when observations were made on curing without forced ventilation, temperatures were normal for three weeks after the hay was placed in storage on August 10. In the 1945 and 1946 tests with forced ventilation, average temperatures were normal in one period, 4F above normal in one period, and from 1 to 4F below normal in the other four periods. Departures from normal weather conditions are not thought to have caused any unusually good or bad results in curing the hay.

## Some Thoughts on Farm Ponds

THE following paragraph is quoted from a letter from one agricultural engineer to another, both of whom have had quite extensive experience with farm ponds:

"We have been giving quite a bit of thought to ponds of a larger size and for other purposes than those now being constructed. On some soils we think it may be possible to use them for supplemental irrigation. Such usage would require that they be placed on larger drainage areas than those now recommended. It would also necessitate some sort of mechanically controlled outlet. I believe our greatest need is for research on the subject of supply, use, requirements, design of outlets, and distribution systems in upland areas. Also, we would like to know if it would be workable or feasible to build a pond having a surface area of, say, 3 to 5 acres on a 30 to 60-acre drainage area and use it for the multiple purposes of recreation, fish production, livestock water supply, supplemental irrigation, and water flow retardation."



*Left:* No forms are needed when precast unit floors are used. Big plank-like units, usually cored, are hoisted up and wheeled into place. After the floor is placed it is covered with a portland cement grout. The grout runs down between the units, bonding them tightly together. There are numerous types of precast floors manufactured. The underside is smooth and can be plastered or painted • *Right:* Concrete joists are used in the same manner as wood joists — spanning from supporting beam to supporting beam or from bearing wall to supporting beam
(Photo courtesy of Portland Cement Association)

# RESEARCH NOTES

**A.S.A.E. members and friends are invited to supply, for publication under this heading, brief news notes and reports on research activities of special agricultural engineering interest, whether of federal or state agencies or of manufacturing and service organizations. This may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Mich.**

### TWO NEW FARMHOUSE BULLETINS

COMING off the press this month is the first in the USDA "Your Farmhouse" series of publications, which is planned to include 18 bulletins helpful to farm families in improving their housing whether by new construction or by repairing, remodeling, and modernizing. The first of these bulletins is Miscellaneous Publication 622, "Your Farmhouse: Cutouts To Help Planning." It is a joint publication of the Bureau of Human Nutrition and Home Economics, the Extension Service, and USDA agricultural engineers.

Concerned with developing skill in planning, the bulletin provides cutouts of house furniture and equipment and a scale card with which cutouts of rooms can be made to the same scale of ½ in equals 1 ft. A family planning to build a new house can select or develop a plan suitable to their needs, make a cutout for each room, and determine quickly whether the furniture and equipment they have or plan to get can be arranged satisfactorily. Dimensioning is carefully done and cutouts for a large selection of furniture in different sizes are given. Also included are cutouts for rugs, clothes closet hanger space, stairs, chimneys and fireplaces, windows, and doors.

In planning for remodeling the farm family starts with a cutout scale plan of the house as it is. Ideas for changes in number, size, and location of rooms are developed in small freehand sketches and selected ones cut out to scale and tested with the furniture. The bulletin provides a check list to help the prospective builders or remodelers decide whether they are satisfying their most important requirements. With the help of county agents and home demonstration agents, use of this very practical bulletin should make farm home building less haphazard and take out much of the guesswork.

The second bulletin in this series, Miscellaneous Publication 619, "Your Farmhouse: How To Plan Remodeling," should be available early in July. Prepared jointly by architects of the Division of Farm Buildings and Rural Housing (BPISAE) and specialists of the Housing and Household Equipment Division (BHNHE), it tells how an actual Wisconsin farmhouse was remodeled by the owners in cooperation with the USDA and University of Wisconsin.

Both publications will be for sale by the Superintendent of Documents. The price of "Cutouts To Help in Planning" has been set at 25 cents and of "How To Plan Remodeling" at 15 cents.

### CASELESS PADDLE-WHEEL FAN

C. F. Kelly, enginer, Division of Farm Buildings and Rural Housing, USDA, has developed a fan for use in corn drying which can be built in the farm shop or by the country blacksmith.

Of three fans which Kelly constructed and tested in the agricultural engineering laboratory at Iowa State College, the caseless paddle-wheel fan proved most satisfactory in several respects. It is easiest to construct with limited equipment. Less difficulty is encountered in balancing the paddle-wheel fan than the disk fans, because the paddle-wheel is lighter in weight and operates at a lower speed for a given power input. Furthermore, with a given amount of corn the paddle-wheel fan becomes more efficient and disk fans less efficient as the depth of corn is increased.

The USDA paddle-wheel or straight radial-blade-type fan differs from the typical commercial centrifugal fan ordinarily used for corn drying in that it has no case and the blades or paddles are flexible. When the fan is installed in the driveway of a double crib (or any other large enclosed room) with the fan inlet extending out into the open air, the driveway acts as a plenum chamber. A static pressure useful for forcing air out horizontally through the corn can thus be built up without the use of a fan casing.

The fan's six flexible blades are made of canvas belting. Centrifugal force causes them to extend radially as soon as rotation starts. With the blades extended, the fan is 36 in in diameter. Six spokes of ¾-in cold rolled steel, 9 in long, are welded to a central hub 6 in in diameter. To the end of each spoke a T of ⅜-in cold rolled steel, 6 in long, is welded parallel to the fan shaft. The fan blades, each 6x9 in are attached to the T by means of sheet-iron straps and stove bolts. Two pieces of ¼-in plywood 3 ft square, one on each side of the fan and spaced ½ in from the blades, are used to confine the air to the spaces between the blades. One plywood piece has a small hole for the shaft only and the other has a center hole 17 in in diameter which acts as an air inlet.

### PLANS FOR LIGHT TRAP RESEARCH

The use of radiant energy to attract female corn borer moths to traps where they can be destroyed before ovipositing is a possible means of preventing damage to early and late planted sweet corn and hybrid seed corn. This type of control will operate irrespective of the weather. As mentioned in "Research Notes" in a previous issue, the USDA Farm Electrification Division is cooperating with the Purdue Agricultural Experiment Station in pursuing research on light traps for corn borer control. USDA ag engineer on the project is John G. Taylor.

This year's laboratory studies are limited primarily to the determination of the relative attractiveness of different wavelengths of radiant energy. Moths are to be liberated in a darkened room which has two or more regions containing radiant energy of different wavelengths transmitted from a spectrograph.

Field studies will test seven sources of radiant energy at wave lengths varying from 2,537 to 5,780 A (Angstrom units). Traps will be mounted horizontally at approximately 70-ft intervals along the side of a field, their height kept just above the level of the corn. Electrical energy for the traps will be supplied by a mobile 15-kw motor generator. Objectives of future studies will include determination of most effective intensities of radiation and design of new types of electric traps.

The importance of these investigations in Indiana is emphasized by official surveys of European corn borer damage in 1946. Spread of the insect into 45 new counties and two new states (North and South Dakota) is recorded, and loss for the country is estimated at $28,741,000.

### CHALLENGING ENGINEERING QUESTIONS

Agriculture in these postwar years is faced with many challenging questions. In the field of research many of these are in agricultural engineering. On April 30, A. W. Turner, assistant chief in charge of agricultural engineering research in the USDA, presented a number of such questions to a group of 50 radio farm directors ("RFD's") who visited the Agricultural Research Center at Beltsville. The group, key men in broadcasting agricultural information over the nation's radio stations, spent two days in the Department of Agriculture. Following are some of the questions asked by Mr. Turner:

What new equipment and changes in methods are needed for harvesting and curing hay? Dairy nutrition specialists say enough protein is now lost in handling hay to meet the requirements of 7½ million cows for six months. Replacement of awkward, inefficient, and antiquated methods in haying is largely an engineering problem.

What are the economic factors involved in production and fabrication of new fiber crops, such as ramie, sansevieria, and others, on an industry basis? The present world shortage of fibers, especially serious in this country, indicates the pressing need to accelerate research.

Can the potentiometer be used to determine seed viability and growth characteristics? Some experiments have shown rather startling results, indicating that the poteniometer may have untold value to plant breeders.

How much does the producer pay for inefficiency in farm processing plants and small industries handling farm products, and what can engineering do to reduce costs? Output per worker varies as much as 25 per cent in creameries, 800 per cent in milk marketing, and 65 per cent in poultry processing plants.

What do we need to know about housing farm animals to lower costs of production? More attention needs to be given to conditions for production within the farm buildings and for proper design; engineers need scientific data on the heat and moisture production of the various kinds of animals in order to provide the right environment for high production and to protect the structures themselves from damage by decay and other ravages of time.

What are the possibilities in the use of bactericidal, erythemal, and infrared energy in agriculture? Preliminary explorations have already indicated a tremendous need for research in this field of electric radiation.

How valuable is labor done in and about farm buildings caring for crops and livestock and what can engineering do to reduce both time and motion in these operations? In dairying, for example, and in producing poultry and eggs, up to 80 per cent of the labor time is spent in the buildings.

On May 12 to 13 the American Agricultural Editors Association also met in Washington for a program particularly broad in scope which included a meeting with the U. S. Atomic Energy Commission. Among the subjects discussed by government scientists were radio active phosphorus research, animal housing research, and new products from USDA chemical laboratories.

### TOBACCO CURING EXPERIMENTS

Devoted to research in the curing, handling, and marketing of bright-leaf tobacco, a new laboratory under construction by the North Carolina Agricultural Experiment Station at its tobacco branch station at Oxford will be headquarters for the cooperative regional project under the direction of Dr. O. A. Brown, USDA agricultural engineer. The regional project includes work in North Carolina, South Carolina, Virginia, Georgia, and Florida. Funds for the new building—estimated to cost $25,000—were appropriated by the 1947 North Carolina Legislature.

*(Continued on page 272)*

# NEWS SECTION

## Dairy Housing Conference in July

A Dairy Housing Conference, sponsored by the Farm Structures Division of the American Society of Agricultural Engineers will be held at the Hotel Loraine, Madison, Wis., July 22 to 24. The program of the Conference is being arranged by a committee consisting of S. A. Witzel (chairman), F. J. Reynolds, W. F. Keepers, A. R. Schwantes, and R. A. Glaze.

All program sessions will be held at the Hotel Loraine. The registration fee for the Conference will be $5.00 per person, except that students in agricultural engineering will be charged $3.00 each. In addition to accommodations at the Hotel Loraine, housing facilities for students and others who desire them will be available at the University of Wisconsin short-course dormitory, at a price of $3.00 per person for the three-day period.

The program for the forenoon of the first day, Tuesday, July 22, will deal with the general subject of dairy production. It will be opened with a paper on why it is essential to produce clean milk on the farm by Leonard Male of the U. S. Public Health Service. Dr. L. K. Riggs, Kraft Food Co., will then discuss how much more clean milk is worth to the dairy products industry, and he will be followed by Harvey Weavers, chief of the dairy division of the Wisconsin Department of Agriculture, who will discuss how structures and barn equipment contribute to clean milk production. The last subject on the program of this session will be on the efficient production of clean milk. Tom Raine, a Minnesota dairy farmer, will discuss the subject with respect to the pen barn, and arrangements are being made for another dairyman to discuss it from the viewpoint of the stanchion barn.

The program for the afternoon session of July 22 will be devoted to the general subject of research in dairy housing. It will open with a talk by J. R. McCalmont, agricultural engineer, U. S. Department of Agriculture, on the USDA psychroenergetic laboratory at Columbia, Mo. Following this E. E. Heizer, chairman, dairy husbandry department, and S. A. Witzel, professor of agricultural engineering, University of Wisconsin, will discuss, respectively, the animal husbandry and engineering phases of the University of Wisconsin dairy barn research project. Another paper of this session will be presented by Wallace Ashby, agricultural engineer, U. S. Department of Agriculture, on the functional requirements of a dairy barn, and he will be followed by Thayer Cleaver, another USDA ag engineer, who will discuss chore route studies.

For the evening session, arrangements have been made for showing three interesting motion pictures to be loaned for the occasion by Fox River Tractor Co., Portland Cement Association, and International Harvester Co.

The program for the forenoon session of Wednesday, July 23, will be built around the general subject of tools and methods for dairy housing construction. Under the title "Material and Buildings", R. A. Glaze, Weyerhaeuser Sales Co., will discuss lumber; E. D. Anderson, Republic Steel Corp., will talk on steel; W. G. Kaiser, Portland Cement Assn., will talk about cement; J. M. Anderson, Structural Clay Products Institute, will talk about brick and tile, and J. L. Strahan, Asphalt Roofing Industry Bureau, will discuss asphalt products.

## A.S.A.E. Meetings Calendar

June 23 to 25—ANNUAL MEETING, Benjamin Franklin Hotel, Philadelphia.

July 22 to 24 — Dairy Housing Conference, Hotel Loraine, Madison, Wis.

October 23 and 24 — Pacific Northwest Section, Davenport Hotel, Spokane, Wash.

December 15 to 17—FALL MEETING, Stevens Hotel, Chicago.

The second subject on this program is that of insulation, a speaker for which is yet to be selected. R. W. Louden, Louden Machinery Co., will talk on what the barn equipment industry offers the farmer for more efficient dairy production, and three speakers will discuss ventilating equipment for dairy barns — A. E. Waterman, James Mfg. Co.; A. R. Schwantes, formerly of the Insulite Division, M. & O. Paper Co., and R. G. Ferris, Starline, Inc.

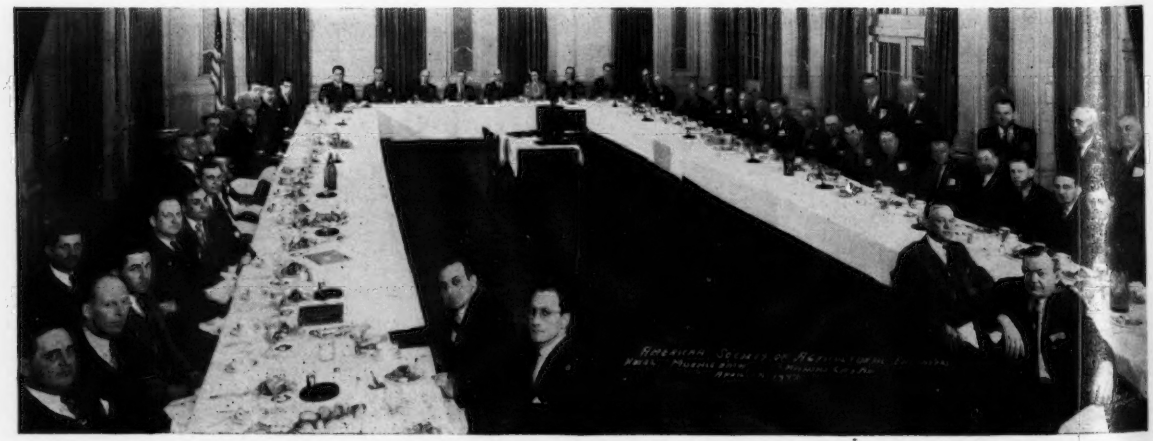
The afternoon of July 23 will be devoted to a tour by bus of several outstanding dairy housing installations in the vicinity of Madison, including the University of Wisconsin dairy barn research project, the Dane County Farm barn, the famous Pet Milk plant at New Glarus, and the Dorsey Segner and John Haldiman farms at Monroe, Wis. Following the tour, arrangements are being made for the group to have dinner in the evening at Turner Hall, in Monroe, where it is expected they will be addressed by W. D. James, president of the James Mfg. Co.

The last session of the meeting, on Thursday forenoon, July 24, will be devoted to two round tables on the functional requirements of two types of dairy structures — the stanchion barn and the loose housing barn with milking parlor. W. Floyd Keepers, secretary, Barn Equipment Association, will act as moderator for the round table on the stanchion barn, with R. W. Louden, Louden Machinery Co.; Wallace Ashby, USDA, and N. N. Allen, University of Wisconsin, as the principal speakers.

Cameron Hervey, assistant editor of "Farm Journal", will act as moderator of the round table on the loose housing barn with milking parlor, with Tom Raine, Minnesota farmer; B. G. Perkins, Doane Agricultural Service, and George Barrett, University of Wisconsin, as the principal speakers.

## Gallagher New Michigan Section Chairman

AT THE first annual meeting of the Michigan Area Section of the American Society of Agricultural Engineers, held in Detroit, May 17, Herman J. Gallagher, farm service supervisor, Consumers Power Company, was elected the new chairman of the Section, succeeding H. E. Pinches. Also elected were three vice-chairmen; Dan W. Guy, agricultural engineer, Ethyl Corp.; Chris Nyberg, chief engineer, Battle Creek Works, The Oliver Corp.; and D. E. Wiant, professor of agricultural engineering, Michigan State College. Frank W. Peikert, professor of agricultural engineering, Michigan State College, was elected secretary-treasurer, and the Nominating *(Continued on page 266)*



First annual dinner of the Missouri Section of the American Society of Agricultural Engineers, at Hotel Muehlebach, Kansas City, Mo., April 17, 1947. The Kansas City Tractor Club acted as host of the occasion

MORE EASE . . .

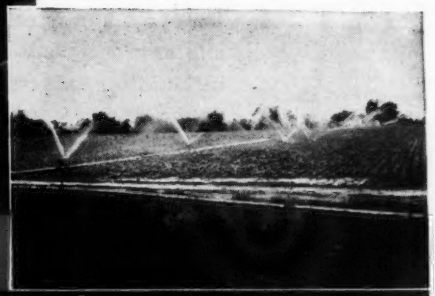
BETTER HEALTH . . .

CONVENIENCE . . . IN THE HOME.

ON THE FARM . . . EFFICIENCY

EASIER CHORES . . .

BETTER CROPS . . .



# A "MUST" for the Modern Farm

## . . . and How to PROVE It

Would you like some help in convincing farm families that a plentiful supply of running water under pressure is a basic requirement for the modern farm? As part of its newest farm electrification program, *More Power to the American Farmer,* General Electric offers "Running Water on the Farm", a full-color, sound motion picture. This film explains to the farmer the need for an automatic, electric water system on his farm—tells him in an interesting and convincing manner about the greater comfort and convenience in home life—about the more profitable farm operating methods made possible by the installation of an economical and easily maintained electric water-pumping system.

This film, designed to be featured at farm meetings all over the country, is accompanied by a handout booklet, "Running Water—the Farm Necessity" for distribution to each interested farmer. This booklet contains a summary of the film's important points, and other helpful information to guide the farmer in his steps toward obtaining running water on his farm on an adequate basis. Finally, such meetings provide excellent opportunities for the further exchange of ideas and information on this and related farm problems.

This film has a large potential audience. Only about 30% of the nation's farms has electric water pumps. And less than 10% makes full use of running water. To bring these instructive programs to the largest possible number of farmers, your General Electric Farm and Home Dealer or distributor invites your active participation in setting up these meetings in your community. See him today—he will welcome your help and your suggestions. And, if you would like an advance copy of the booklet accompanying the film, send in the coupon below. *Farm Industry Division, General Electric Co., Schenectady 5, N. Y.*

HEALTHIER STOCK . . .

MORE POULTRY PROFIT.

Farm Industry Division
Section A669-49
General Electric Co.
Schenectady 5, N. Y.

Please send me copy of GES-3391, "Running Water—The Farm Necessity."

Name .....

Occupation .....

Street Address .....

City ..... State .....

GENERAL ELECTRIC

## Personals of A.S.A.E. Members

*L. E. Bartlett* has resigned as special representative of the American Lumber and Treating Co., to accept a position with the T. R. Miller Mill Co., Brewton, Ala., where he will be in charge of treated lumber sales.

*Ralph J. Bugbee,* in charge of rural electrification activities of the Central Vermont Public Service Corp., is doubtless largely responsible for his company being the recipient of the 1947 Martin Award which is made annually by the Edison Electric Institute "to the electric operating company which makes the greatest contribution to the progress of rural electrification and agricultural advancement within the company's territory".

*Chester P. Davis, Jr.,* recently joined the staff of the farm industry division of General Electric Company to deal with agricultural engineering problems.

*Roy E. Hayman* was recently appointed agricultural development engineer of the southwest division of the Public Service Co., of Oklahoma with headquarters at Chickasha, Okla. Mr. Hayman has a long, excellent record in rural electrification work in his state.

*David Meeker* has resigned as manager of the education of Harry Ferguson, Inc., to become director of education of the Dearborn Motors Corporation, Detroit, Mich. From 1941 to 1943, Mr. Meeker was assistant director of the Office of Agricultural Defense Relations, and in 1943 was appointed chief of the Farm Machinery and Supplies Branch of the War Food Administration. Later he was made director of the Office of Surplus Property and Reconversion, and recently he was appointed by the Secretary of Agriculture to the joint USDA-land-grant college policy committee.

*Robert P. Messinger* has been advanced from the position of vice-president in charge of the farm implement division of the International Harvester Company to the position of vice-president in charge of the Company's foreign operations.

*Leland E. Morgan* has been transferred from research associate in agricultural engineering, Louisiana Agricultural Experiment Station, to assistant agricultural engineer in the Louisiana Agricultural Extension Service.

*Robert H. Smith,* for many years instructor in farm mechanics at the New York Agricultural and Technical Institute, at Canton, is now associated with the Robinson Farm Equipment Co., International Harvester retail farm equipment dealers of that city.

*Herbert N. Stapleton* has accepted a position as research professor of agricultural engineering at the Massachusetts Agricultural Experiment Station. His previous position was that of agricultural engineer for the Green Mountain Power Company at Shelburne, Vermont.

*James W. Stratton* who served in the Army Air Forces during the war is now employed as soil engineer with the Bureau of Reclamation, U. S. Department of the Interior, at Ephrata, Wash.

*Henry E. Wichers,* formerly professor of architecture, Kansas State College, is now extension specialist in rural housing at the State College of Washington, Pullman.

## N.R.S.S.P. Publications

THE National Roster of Scientific and Specialized Personnel, U.S. Department of Labor, recently announced a "Description of Professions" series of seven pamphlets introducing briefly the agricultural and biological sciences, engineering sciences, medical service occupations, medical professions, miscellaneous professional fields, physical sciences, and social sciences.

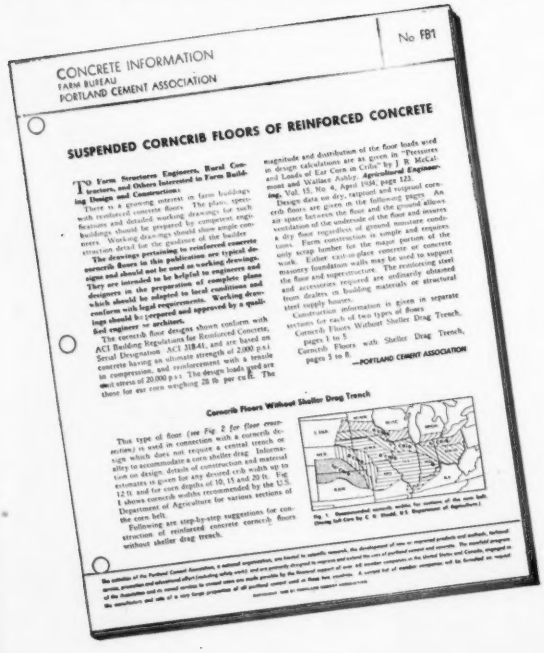
At the same time it published a tabular "Distribution of Roster Registrants" by professional field, sex, age, and extent of education, as of December 31, 1946, and a price list of its publications to March, 1947.

Agricultural engineering is covered in three pages of the description of enginering sciences, approximately the same space given to other branches of engineering, with subheadings on occuptational summary, major branches, functional specializations; licensure, professional affiliations, and civil service ratings; educational qualifications, related professional fields, and sources of employment. A limited supply is available for free distribution on request to the National Roster, and additional copies are available from the Superintendent of Documents, U. S Government Printing Office, Washington, D. C., at 15 cents.

The N.R.S.S.P. also has covered agricultural engineering in a separate handbook of descriptions in specialized fields, available at 5 cents per copy from the Superintendent of Documents.

Copies of the Distribution of Roster Registrants are available free on request to the National Roster. It shows a total of 806 agricultural engineers on the Roster, and their distribution.


# How to design Dry, Ratproof Concrete Floors for Corncribs


CONCRETE INFORMATION
FARM BUREAU
PORTLAND CEMENT ASSOCIATION

No FB1

SUSPENDED CORNCRIB FLOORS OF REINFORCED CONCRETE

To Farm Structures Engineers, Rural Contractors, and Others Interested in Farm Building Design and Construction:

There is a growing interest in farm buildings with reinforced concrete floors. The plans, specifications and detailed working drawings for such buildings should be prepared by competent engineers. Working drawings should show ample construction detail for the guidance of the builder.

**The drawings pertaining to reinforced concrete corncrib floors in this publication are typical designs and should not be used as working drawings. They are intended to be helpful to engineers and designers in the preparation of complete plans which should be adapted to local conditions and conform with legal requirements. Working drawings should be prepared and approved by a qualified engineer or architect.**

The corncrib floor designs shown conform with ACI Building Regulations for Reinforced Concrete, Serial Designation ACI 318-41, and are based on concrete having an ultimate strength of 2,000 p.s.i. in compression, and reinforcement with a tensile stress of 20,000 p.s.i. The design loads used are those for ear corn weighing 28 lb. per cu.ft. The magnitude and distribution of the floor loads used in design calculations are as given in "Pressures and Loads of Ear Corn in Cribs" by J. B. McCalmont and Wallace Ashby, *Agricultural Engineering*, Vol. 15, No. 4, April 1934, page 122.

Design data on dry, ratproof and ventilated corncrib floors are given in the following pages. An air space between the floor and the ground allows ventilation of the underside of the floor and insures a dry floor regardless of ground moisture conditions. Form construction is simple and requires only scrap lumber for the major portion of the work. Either cast-in-place concrete or concrete masonry foundation walls may be used to support the floor and superstructure. The reinforcing steel and accessories required are ordinarily obtained from dealers in building materials or structural steel supply houses.

Construction information is given in separate sections for each of two types of floors:
Corncrib Floors Without Sheller Drag Trench, pages 1 to 5.
Corncrib Floors with Sheller Drag Trench, pages 5 to 8.

—PORTLAND CEMENT ASSOCIATION

Corncrib Floors Without Sheller Drag Trench

This type of floor (see *Fig. 2* for floor construction) is used in connection with a corncrib design which does not require a central trench or alley to accommodate a corn sheller-drag. Information on design, details of construction and material estimates is given for any desired crib width up to 12 ft. and for corn depths of 10, 15 and 20 ft. Fig. 1 shows corncrib widths recommended by the U.S. Department of Agriculture for various sections of the corn belt.

Following are step-by-step suggestions for construction of reinforced concrete corncrib floors without sheller drag trench.

DRY, ratproof storage facilities for money crops such as corn, are of increasing interest to farmers. An air space between a concrete floor and the ground allows ventilation of the underside of the floor and insures a dry floor regardless of ground moisture conditions.

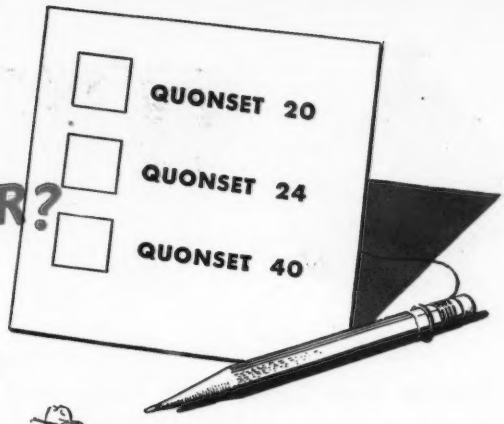
Our concrete information sheet, "Suspended Corncrib Floors of Reinforced Concrete", gives the engineer complete design data—describes every step in building corncrib floors with or without sheller drag trench.

Agricultural engineers may have a free copy of this new folder on request. Distributed only in United States and Canada.

**PORTLAND CEMENT ASSOCIATION**
**Dept. A6-1, 33 W. Grand Ave., Chicago 10, Illinois**

A national organization to improve and extend the uses of concrete . . . through scientific research and engineering field work

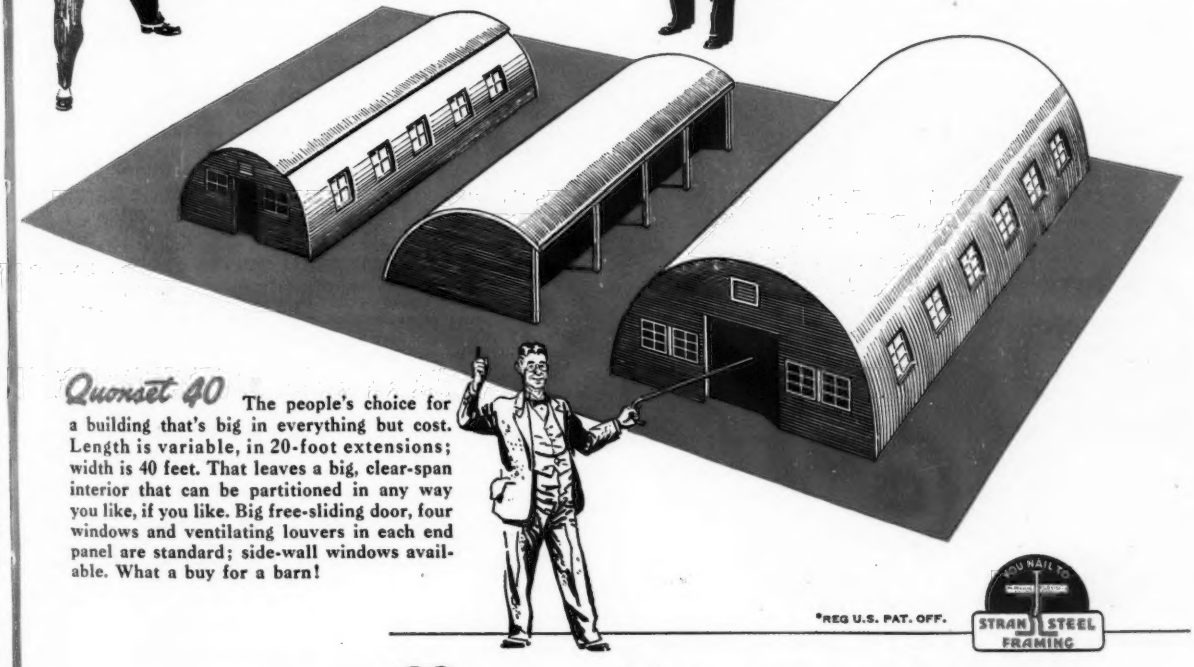
# WHICH Quonset* ARE YOU GOING TO VOTE FOR?




***Here are their platforms and qualifications:***

**Quonset 20** War veteran with a great service record. Won military commendation for ease and speed of erection, utility and strength. Claims "without fear of successful contradiction" to be the world's most versatile building. All-steel, and 20 feet wide. Length variable, in 12-foot extensions. Walk door, two windows and ventilating louvers in end walls standard; side-wall windows also available.

**Quonset 24** A vote for the Quonset 24 is a vote for finer farm buildings. It stands for better storage space for animals, vehicles, tools . . . and *keeps* on standing for years and years. Very adaptable to changing needs. Width, 24 feet; length to suit, in 12-foot sections, with choice of open front, solid panel or sliding door in each section. Standard end wall is solid, but end-wall door and window are available.



**Quonset 40** The people's choice for a building that's big in everything but cost. Length is variable, in 20-foot extensions; width is 40 feet. That leaves a big, clear-span interior that can be partitioned in any way you like, if you like. Big free-sliding door, four windows and ventilating louvers in each end panel are standard; side-wall windows available. What a buy for a barn!

*REG U.S. PAT. OFF.

YOU NAIL TO STRAN-STEEL FRAMING

*Whichever way you vote—*

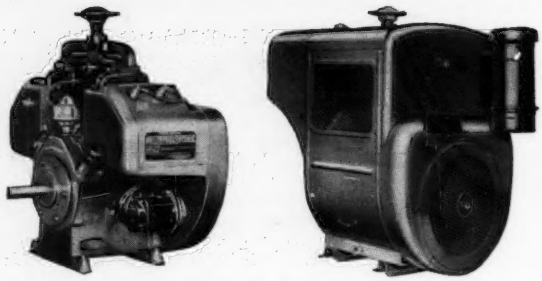
***You Get a Strong, Sturdy, Fire-Resistant Farm Building***

You really can't go wrong with a Quonset—*any* Quonset. All three share the sturdiness, the fire-resistance and the permanence of all-steel construction. And all three bring you the simplicity and flexibility of Stran-Steel framing, with its exclusive nailing groove for attaching other materials. Quonsets go up in a hurry, and won't sag, warp or rot or be bothered by termites. See your local Quonset dealer for full details, or write for his name if you don't know it.

## GREAT LAKES STEEL CORPORATION

**Stran-Steel Division • Dept. 27 • Penobscot Bldg. • Detroit 26, Mich.**

**UNIT OF NATIONAL STEEL CORPORATION**



*Let this 20-Horse Team*

**Handle Your Heavy-Duty Power Jobs**

Turning up 20.5 hp. at 2200 R.P.M. the Model VE-4 WISCONSIN Standard Air-Cooled Engine (left) and the Model VE-4 Complete Power Unit (right), can always be depended upon for continuous, heavy-duty operation in any kind of service, on any kind of equipment within their power range.

Positive, trouble-free AIR-COOLING; dynamically balanced crankshaft mounted on tapered roller bearings, *front* and *rear;* high tension magneto with impulse coupling for quick, easy starting in any weather . . . these are features that you can bank on for top performance.

***Specify Wisconsin Air-Cooled Engines for YOUR equipment . . . for most hp.-hours of service, at the lowest overall cost.***

Most H.P. per pound

**WISCONSIN MOTOR**
Corporation
MILWAUKEE 14, WISCONSIN, U. S. A.
*World's Largest Builders of Heavy-Duty Air-Cooled Engines*

**BELT LACING and FASTENERS** for transmission and conveyor belts

"JUST A HAMMER TO APPLY IT"

**ALLIGATOR**
Trade Mark Reg. U. S. Pat. Office

**STEEL BELT LACING**

World famed in general service for strength and long life. A flexible steel-hinged joint, smooth on both sides. 12 sizes. Made in steel, "Monel Metal" and non-magnetic alloys. Long lengths supplied if needed. Bulletin A-60 gives complete details.

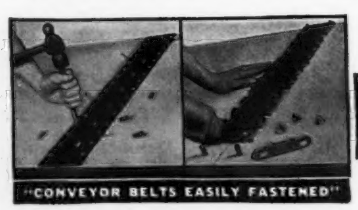
**FLEXCO HD**

**BELT FASTENERS AND RIP PLATES**

For conveyor and elevator belts of all thicknesses, makes a tight butt joint of great strength and durability. Compresses belt ends between toothed cupped plates. Templates and FLEXCO Clips speed application. 6 sizes. Made in steel, "Monel Metal", non-magnetic and abrasion resisting alloys.

By using Flexco HD Rip Plates, damaged conveyor belting can be returned to satisfactory service. The extra length gives a long grip on edges of rip or patch. Flexco Tools and Rip Plate Tool are used. For complete information ask for Bulletin F-100.

***Sold by supply houses everywhere***



"CONVEYOR BELTS EASILY FASTENED"

**FLEXIBLE STEEL LACING CO.**

**4677 Lexington St.**
**Chicago, Ill.**

## NEWS *(Continued from page 262)*

Committee consists of J. C. Cahill, Detroit Edison Company; A. W. Farrall, Michigan State College, and J. W. Shields, United States Rubber Company.

Approximately 70 A.S.A.E. members and guests attended the Section meeting, the program of which included two outstanding features: a report on a study of farm machinery costs and requirements for Michigan farms by W. N. Hart of Michigan State College, and a motion picture showing a design of farm structures for improved efficiency presented by W. R. Peterson, agricultural engineer, International Harvester Company.

Following the program and luncheon, a tour was made through the United States Rubber Company's tire factory where the production of rubber tires was observed.

## 1948 A.S.A.W. Convention in Washington

ANNOUNCEMENT was made last month of the decision to hold the 1948 annual convention of the Association of Southern Agricultural Workers in Washington, D. C., February 12, 13, and 14. Heretofore this meeting has usually been held somewhere in one of the southeast states.

## Summer Course in Rural Housing

THE University of Illinois, College of Agriculture, Urbana, Illinois, has announced a full-time graduate course in rural housing, for the period July 7 to August 2, 1947. Deane G. Carter, professor of farm structures, will handle the course, assisted by Miss Margaret Goodyear of the home economics department. "This work will be offered at the graduate level of one unit of credit, equivalent to four or five semester hours", Professor Carter said. "One-half of the course covers the problems of functional planning, remodeling, home improvements, and housing requirements. Special problems portion of the course will deal with each student's field of interests and include use of visual aids, educational programs, and applications."

This course is intended primarily for women who want special training in housing; however, arrangements have been made to admit men students who will enroll in agricultural engineering courses. Further details regarding the course, enrollment, cost, etc., will be supplied by Professor Carter who should be addressed in care of the agricultural engineering department, University of Illinois, Urbana.

## Midwest Flood Control Conference

A Midwest Flood Control Conference is to be held at Indianapolis, Indiana, June 18 to 20.

David H. Harker, chief engineer of the Indiana Flood Control Commission, is general chairman for the conference, which is said to be "the first attempt of midwestern states to get together among themselves and with federal agencies in determining how flood control problems can better be studied and solved."

States included in the area to be considered are Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, Oklahoma, Pennsylvania, Tennessee, West Virginia, and Wisconsin.

Federal agencies expected to be represented include the Corps of Engineers, U. S. Army; Soil Conservation Service, Forest Service, and Weather Bureau of the U. S. Department of Agriculture, and the Bureau of Reclamation and Geological Survey of the U. S. Department of the Interior.

One of the featured speakers will be J. C. Dykes, assistant chief of the U. S. Soil Conservation Service. Land use and other agricultural considerations in flood-control planning are to be adequately represented.

An attendance of between 200 and 300 is expected. The conference is to be held at the Severin Hotel.

## Necrology

HENRY CHARLES GOTCHER was fatally injured May 16, near Ardmore, Oklahoma, when he encountered unfavorable weather in his personal plane. He was attempting a forced landing under poor visibility conditions when his plane struck trees, exploded, and burned.

He was born at Sherard, Mississippi, October 10, 1915; and majored in agricultural engineering at Mississippi State College obtaining his bachelor of science degree in 1937. While in school he had been a member of the student branch of the American Society of Agricultural Engineers.

After his graduation, Mr. Gotcher had returned to his home to work on the family cotton plantation. His progressive mechanization of the operations led to his development of a propane-burning flame cultivator in 1944, and to the formation of the Gotcher Engineering and Manufacturing Co., of which he was president and designing engineer at the time of his passing.

He had been elected a member of A.S.A.E. in June, 1946, and was scheduled to present a paper on "Mechanical Features of Flame Cultivators", June 23, at the annual meeting of the Society in Philadelphia.

# ROCKS and STONES never daunt these Ingersoll "Super-Alloy" discs . . .

**These discs minimize breakage . . .**

When rocks catch their edges the discs resist splitting or chipping because they're tough, heat treated Nickel-chromium steel.

Many different alloys were tested under severe tillage conditions before Ingersoll Steel Division of Borg-Warner Corporation succeeded in developing this special steel . . . now well known as "Super-Alloy."

Corresponding to Type 3160 steel in Nickel, chromium and carbon content, "Super-Alloy" gives harrow discs extra stamina for long, trouble-free performance in rocky soil where ordinary metal discs tend to break or wear excessively.

Parts fabricated from steels alloyed with Nickel provide extra stamina. That's why Minneapolis-Moline Power Implement Company, maker of the Wheatland Disc Plow and tractor, shown above, use numerous Nickel steel parts, including gears and axles for all their tractors.

*Field scene showing Minneapolis-Moline's Universal Tractor and Wheatland Disc Plow.*

Over the years, International Nickel has accumulated a fund of useful information on the selection, fabrication, treatment and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes and other alloys containing Nickel. This information and data are yours for the asking. Write for "List A" of available publications.

EMBLEM OF INCO SERVICE
TRADE MARK

**THE INTERNATIONAL NICKEL COMPANY, INC.** 67 WALL STREET NEW YORK 5, N.Y.

One of the strongest selling statements that can be made regarding any engine-powered equipment is this:

"It's Powered with a FORD-BUILT ENGINE!"

Engines available through district sales offices of Ford Motor Company or through Ford Dealers. Universal Ford Service always available everywhere.

Ford

FOURS · SIXES · V-EIGHTS

Write For Latest Industrial Literature

Address:

FORD MOTOR COMPANY

Industrial and Marine Engine Department

3519 SCHAEFER ROAD · DEARBORN, MICHIGAN

EWC WHEELS

Engineered for YOUR Product

There is a wide variety of EWC wheels and axles for every type of mobile equipment . . . one or several may be ideally suited to your product. For unusual wheel problems, we offer you a complete engineering service, with a thoroughly experienced staff and unexcelled facilities. Write today for complete information.

ELECTRIC WHEEL CO., Quincy, Illinois, Est. 1890

## Applicants for Membership

**The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.**

*M. Conner Ahrens,* Pine Manor, Pullman, Wash.

*Kenneth K. Barnes,* graduate student in agricultural engineering, Iowa State College, Ames, Iowa. (Mail) 495 Pammel Court.

*Donald R. Burrowbridge,* agricultural engineer, Illinois Northern Utility Co. (Mail) Belvidere, Ill.

*Mathis R. Bush,* 631 West 6th St., Chattanooga, Tenn.

*Arnold B. Fischer,* soil and water conservation contractor, 309 North 7th Street, Sedalia, Mo.

*Herman W. Glover,* Cleveland, Georgia.

*Harold E. Gulvin,* instructor and extension specialist in agricultural engineering, Rhode Island State College, Kingston, R. I.

*Md. Fazlul-Haque,* suboverseer, Under Government of Bengal. (Mail) c/o S. M. Najmal-Haque, Agricultural Engineering Dept., Cornell University, Ithaca, N. Y.

*H. Conley Hayes,* farm utilization supervisor, Pennsylvania Power & Light Co., Williamsport, Pa. (Mail) 1633 Scott St.

*Heggie N. Holtan,* agricultural engineer, Soil Conservation Service (Research), USDA. (Mail) R. R. No. 1, Box 117, Blacksburg, Va.

*Burton S. Horne,* instructor, farm training courses, Veterans Administration. (Mail) Ringtown, Pa.

*David A. Horner,* R. R. No. 3, Columbia, Mo.

*Arthur L. Jess,* agricultural engineer, Bureau of Land Management, USDI. (Mail) The Dalles, Ore.

*Bernard C. Mathews,* vice-president, American Crop Drying Equipment Co., R. R. No. 2, Crystal Lake, Ill.

*Walter E. Matson,* student in agricultural engineering, Washington State College. (Mail) R.R. No. 1, Box 32, Kalama, Wash.

*Adolphus J. Miller,* assistant professor of agricultural engineering, Virginia State College, Petersburg, Va.

*Doremus L. Mills,* development engineer, Revere Copper and Brass, Inc., Rome, N. Y.

*Clement L. Montgrain,* rural electrification specialist, Rural Electrification Bureau, 89 E. Notre Dame St., Montreal, Quebec, Canada.

*C. L. Roberts,* special tillage traveler, International Harvester Co. (Mail) 2500 Illinois Ave., South Gate, Calif.

*Robert R. Robinson,* manager, Robinson Ventilating Co., Zelienople, Pa.

*Vernon Selde,* Davenport, Wash.

*Maurice W. Shier,* manager, Shier & Shier, conservation contractors, R. R. No. 5, Sparta Road, St. Joseph, Mo.

*Mark E. Singley,* instructor in agricultural engineering, College of Agriculture, Rutgers University, New Brunswick, N. J.

*Edwin F. Wadelton,* design engineer, Killefer Mfg. Corp. (Mail) P. O. Box 262, Whittier, Calif.

*Harold V. Walton,* instructor in agricultural engineering, Pennsylvania State College, State College, Pa.

*Leo T. Wendling, Jr.,* agricultural engineer, Soil Conservation Service, USDA. (Mail) Syracuse, Kans.

*H. D. Wittmus,* student in agricultural engineering, University of Nebraska. (Mail) Papillion, Nebr.

TRANSFER OF GRADE

*Herold F. Bruns,* agricultural engineer, The Toledo Edison Co., Defiance, Ohio. (Mail) R. R. No. 2. (Junior Member to Member)

*Harold J. Butler,* partner, Butler & Hendrickson, Hector, Minn. (Junior Member to Member)

*James E. Day,* agricultural engineer, Soil Conservation Service, USDA. (Mail) 708 East Center St., Searcy, Ark. (Junior Member to Member)

*George W. French,* assistant agricultural engineer (BPISAE) USDA. (Mail) Agricultural Engineering Department, Michigan State College, East Lansing, Mich. (Junior Member to Member)

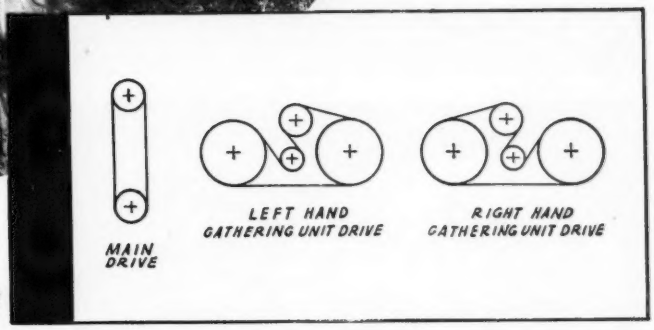
*Winfred G. Glover,* agricultural engineer, Soil Conservation Service, USDA. (Mail) 104 Second St., Prescott, Ariz. (Junior Member to Member)

*R. Henry Jones,* farmer, R. R. No. 3, Box 96, Vicksburg, Miss. (Junior Member to Member)

*J. J. Paterson,* assistant professor of agricultural engineering, University of Manitoba, Fort Garry, Winnipeg, Man., Canada. (Junior Member to Member)

*Fred C. Yoder, Jr.,* farm equipment retailer, Minerva, Ohio. (Mail) 300 E. Line St. (Junior Member to Member)

# do you know ROLLER CHAIN

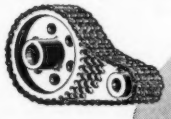



## . . . assures positive picking?

With positive Baldwin-Rex Roller Chain drives on a corn picker, there's less danger of losing or damaging corn. For roller chains assure the exact timing so necessary in the picking and husking operations. There's no slipping to throw the machine out of time with resultant loss of corn.

As the drive design of this corn picker illustrates, roller chains have important advantages that add to the efficiency and over-all compactness. Two or more sprockets can be driven from a single power source, and the chain can be flexed in either direction, features that save considerable space and permit a single drive to turn shafts in opposite directions.

For economy, long life, and the most efficient operation, rely on Baldwin-Rex Roller Chains for all farm equipment drives.



**BALDWIN·REX**

**ROLLER CHAINS**

*Write for complete information on roller chains and for complete information on your specific drive problems. There is no obligation.*

**BALDWIN-DUCKWORTH DIVISION OF CHAIN BELT COMPANY**

**376 Plainfield Street, Springfield 2, Massachusetts**

# Protecting Crops, Machinery, Homes
# SISALKRAFT Does It

On farms — like any other business — every dollar saved is that much profit. Wind, rain, sleet, snow — exposure of every kind — can do much damage to harvested crops, machinery, buildings. With Sisalkraft much of this loss can be avoided.

Sisalkraft is ideal for temporary silos — emergency storage of grain — covering hay stacks — protecting machinery — curing concrete — lining poultry houses — protecting the home — plus many other uses. Costs little. Tough, tear-resistant, and waterproof. Can be used again and again.

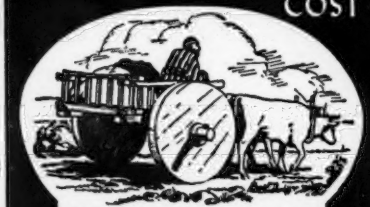
*Sisalkraft is sold through lumber dealers everywhere. Write for folders on Sisalkraft's many farm uses.*

THE SISALKRAFT CO. 205 W. WACKER DRIVE · CHICAGO · ILL. NEW YORK SAN FRANCISCO LONDON SYDNEY

*Manufacturers of* SISALKRAFT, FIBREEN, SISALATION, SISALTAPE AND COPPER-ARMORED SISALKRAFT



# Early Man Wasn't COST CONSCIOUS



*This old fellow would be amazed to see the modern wheeled equipment which has turned want into plenty.*

NOW *it is* DIFFERENT

**Wheels that were adequate for the patient and plodding ancients would be utterly useless today. We demand action — efficiency — speeds — and uninterrupted production — in order that the many may enjoy the fruits of agriculture and industry at lowest possible costs. WHEELS "by French & Hecht" are soundly engineered to meet the exacting demands of TODAY. Mobile equipment is only as strong as the wheels upon which it is mounted. We know how to design, test and produce wheels capable of meeting the responsibilities entrusted to them. Specify WHEELS "by French & Hecht" with confidence.**

***Send Your Wheel Problems to Us***

FRENCH & HECHT
DIVISION
KELSEY-HAYES WHEEL COMPANY
DAVENPORT, IOWA
*WHEEL BUILDERS SINCE 1888*


## *Personnel Service Bulletin*

**The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration or license as a professional engineer.**

NOTE: In this Bulletin the following listings still current and previously reported are not repeated in detail. For further information see the issue of AGRICULTURAL ENGINEERING indicated.

Attention is invited to the desirability of checking on the housing situation when considering a new location.

POSITIONS OPEN: 1946 MAY—O-503. JUNE—O-506. AUGUST—O-510. SEPTEMBER—O-516. NOVEMBER—O-523. DECEMBER—O-526, 531. 1947 FEBRUARY—O-540, 541. MARCH—O-543, 547. APRIL—O-549, 550, 551, 552, 555, 556, 557. MAY—O-558, 559, 560, 561, 562, 563, 564.

POSITIONS WANTED: 1946 FEBRUARY—W-207. APRIL—W-237. MAY—W-309. JUNE—W-320. SEPTEMBER—W-337. 1947 FEBRUARY—W-373. MARCH—W-380, 382. APRIL—W-383, 386, 387, 388, 389. MAY—W-392, 393, 394, 395, 397, 398, 399, 100, 101, 102, 103.

### NEW POSITIONS OPEN

**CHIEF ENGINEER** to head development and production engineering in farm machinery manufacturing organization. Location, Pennsylvania. Want man with experience in responsible position in farm machinery field, and demonstrated ability as an engineering leader with capacity for management. Top position. Age, middle. Salary, high. O-565

**AGRICULTURAL ENGINEER** (instructor or assistant professor rank) for teaching in irrigation, water conservation, and other phases of agricultural engineering, in a north central state college. BS or MS deg in agricultural engineering, with good personality, appearance, and ability to conduct classes. Some practical experience in irrigation highly desirable. Age, 25 - 35. Salary $3400-$4000. O-566

**AGRICULTURAL ENGINEER** (associate professor rank) to take complete charge of research in farm housing, in a midwestern state university. BS or MS deg in architecture, with experience in farm building field. Usual personal requirements for college work. Age, 30 - 40. Salary, up to $4500 depending on qualifications. O-567

**AGRICULTURAL ENGINEER** for teaching machinery and related subjects in southern university. Instructor, assistant, or associate professor rank. Salary $3,000 to $5,000, depending on qualifications. BS deg in agricultural engineering required. O-568

**AGRICULTURAL ENGINEER**, for development work in farm machinery in southern state. BS deg in agricultural engineering required. Beginning salary $3200 for eleven months. O-569

**AGRICULTURAL ENGINEER** for research in crop processing in southern state. BS deg in agricultural engineering required. Beginning salary $3200 for eleven months. O-570

**AGRICULTURAL ENGINEER** with experience in tobacco growing, for research in flue curing equipment. A recent BS graduate in agricultural engineering, interested in working on MS degree would find this an excellent opportunity in a new field. O-571

**AGRICULTURAL ENGINEER** for teaching farm shop work in southern state, BS deg in agricultural engineering required. Instructor or assistant professor rating, with salary ranging from $3000 to $3800 depending on education and experience. O-572

**AGRICULTURAL ENGINEER** (assistant professor rank), for research and some teaching, mostly in machinery for diversified tropical agriculture, in Hawaii. BS deg, or higher, in agricultural engineering or equivalent. Agricultural background, thorough knowledge of engineering fundamentals, usual qualifications for college and research work, plus interest in machine design. Close association with related work in sugar cane and pineapple production fields. Housing situation difficult, available housing described upon application. Salary $4356-$5316. O-573

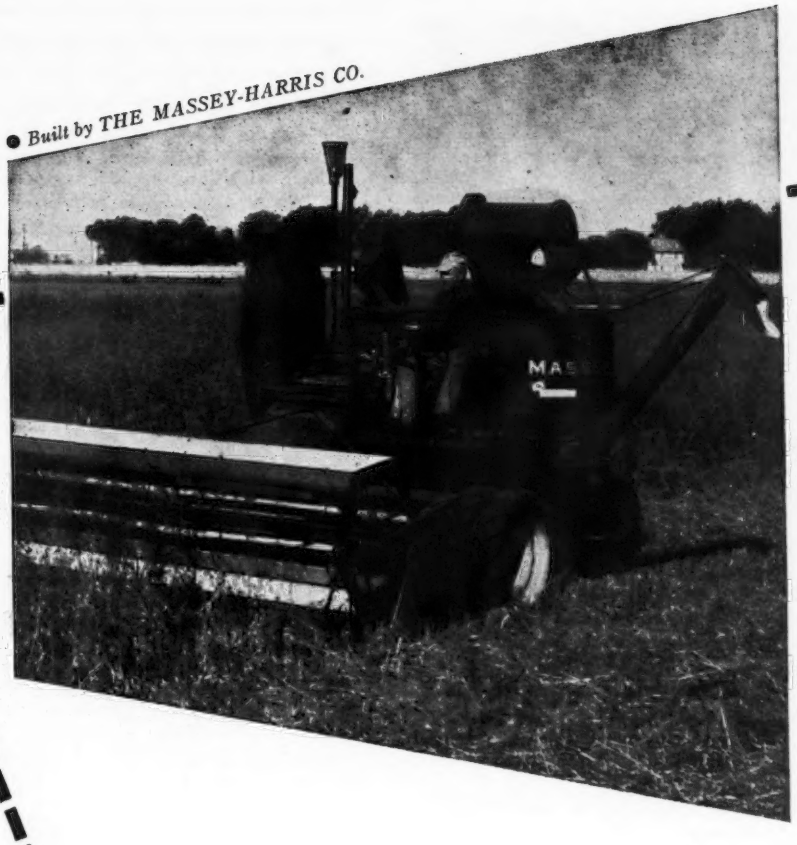
### NEW POSITIONS WANTED

**AGRICULTURAL ENGINEER** desires work in soil and water conservation in public service; farm machinery design or service in private industry; or work in extension service. BS deg in agricultural engineering, University of Tennessee, 1947. Apprentice draftsman of soil maps, 9 mo.; blueprint machine operator, 6 mo.; enlisted service in Infantry, 4½ years. 9/15 hearing in right ear, due to blast, no handicap. Available July 1. Single. Age 25. Salary open. W-104

**AGRICULTURAL ENGINEER** desires research or sales engineering in the soil and water field, or engineering in the processing of farm products. BS deg in agricultural engineering, University of Tennessee, 1947. Surveying 3 mo part time as co-op student; salesman in department stores, part time; infantry enlisted and commissioned service, 3 yrs., including troop command in Burma and China, and duty as ration purchasing officer for Chinese government. No physical defects. Available on short notice. Single. Age 24. Salary $2800. W-105

*(Continued on page 272)*

● *Built by* THE MASSEY-HARRIS CO.



## 100 Years of Progress

It was in 1847 that Daniel Massey, a Vermont farmer, started making farm tools for his neighbors. His neighbors liked them, and eventually The Massey-Harris Company was producing equipment for farmers everywhere. In 1944-45, for instance, the 21-A Self-Propelled Combine pictured above played an outstanding role in the work of multi-million acre harvest brigades. Many improvements and refinements have appeared since 1847—among them the anti-friction bearing. Today, 100 years later, vital rotating parts of Massey-Harris products depend upon SKF Bearings, for SKF Ball and Roller Bearings improve efficiency and reduce operating costs. Because SKF makes many types of anti-friction bearings, SKF engineers are in a position to give you expert help in selecting the right bearing for the right place. 6262

SKF INDUSTRIES, INC.
Front St. & Erie Ave., Phila. 32, Pa.

**SKF**
**BALL AND ROLLER BEARINGS**

Cultivating a contoured field with Farmall A. Corn and hay are planted in alternate strips.

*The Favorites Year After Year . . .*

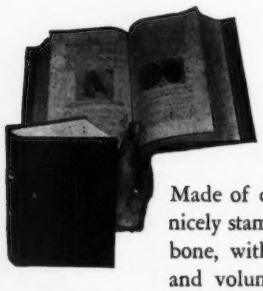
**FARMALL TRACTORS**

Farmers today want FARMALLS more than any other make of tractor. They know that with these versatile tractors they can carry out terracing, contouring and other soil conservation methods. In the Farmall System of Farming, there is complete equipment for every approved farming practice.

As new machines are designed by Harvester engineers for specific jobs, they are adapted to the Farmall System to bring every farming region the diversification and specialization of farm machinery it needs . . . to attain the best returns from the soil and increase farm profits.

**INTERNATIONAL HARVESTER COMPANY**
180 North Michigan Avenue CHICAGO 1, ILLINOIS

A Handsome, Permanent Binder *for* AGRICULTURAL ENGINEERING



*only* $1.40

The ONLY binder that opens flat as a bound book! Made of durable imitation leather, nicely stamped on front cover and backbone, with name of journal and year and volume number, it will preserve your journals permanently. Each cover holds 12 issues (one volume). Do your own binding at home in a few minutes. Instructions easy to follow. Mail coupon for full information, or binder on 10-day free trial.

MAIL COUPON TODAY

SUCKERT LOOSE-LEAF COVER CO.
234 West Larned St., Detroit, Mich.

*Mail postpaid.....binders for Agricultural Engineering for years.....*
*Will remit in 10 days or return binders collect.*

Name.....

Address.....

City.....State.....

## PROFESSIONAL DIRECTORY

**GEORGE R. SHIER ROBT. J. McCALL**
**Professional Agricultural Engineering Services**
Structures, Ventilation, Drying, Machinery Development and Sales Consultation, Engineering Design
Members A.S.A.E. Room 705, 8 E. Broad St., Columbus 15, Ohio

**FRANK J. ZINK ASSOCIATES**
**Agricultural Engineers**
**Consultants on product development, designs, research, market research, public relations**
FELLOW A.S.A.E. MEMBER S.A.E. Telephone: Harrison 0723 Suite 4300, Board of Trade Bldg. Chicago 4, Illinois

RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to A.S.A.E. members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.

## PERSONNEL SERVICE BULLETIN

*(Continued from page 270)*

**ELECTRICAL ENGINEER in India desires American experience in rural electrification, development, research, teaching, extension or project engineering. BS deg in mechanical and electrical engineering, Benares Hindu University, 1940. Experience in Imperial Agricultural Research Institute, as technical assistant to Imperial Agriculturist, on research and maintenance of farm machinery, 4 years; lecturer on electrical engineering and machine design, Allahabad Agricultural Institute, 1 year; power station engineering, Cawnpore Electric Supply Corporation, 2 yrs. Available any date after September, 1947, subject to passport and voyage accommodations. Married. Age 34. Salary $3000. W-106**

## New Literature

1946 BOOK OF A.S.T.M. STANDARDS. Cloth or half leather. Five parts. 7000 pages. Illustrated and indexed. American Society for Testing Materials, Philadelphia, Pa. Prices as scheduled. Separately bound parts cover (1) ferrous metals, (2) non-ferrous metals, (3) non-metallic materials — constructional, (4) non-metallic materials — coal and coke, petroleum products, aromatic hydrocarbons, soaps, waters, textiles, gaseous fuels, and (5) non-metallic materials — electrical insulating materials, plastics, rubber, paper, shipping containers, and adhesives. A total of 1400 standards are covered. Supplements are to be published late in 1947 covering subsequent standards and changes.

## Research Notes

*(Continued from page 261)*

In addition to the laboratory, two new tobacco barns are being constructed at the Oxford station. They are of the same design as those built a year ago, but each one will be equipped with a heating system different from those used last year. A third new barn, to be started soon, will be of steel. Various types of ventilators will be studied during this season's curing, as well as all types of fuel.

On the basis of results in the tests so far, Dr. Brown is of the opinion that it should be possible to cure out 700 sticks of tobacco with 700 lb of coal or 70 gal of No. 3 fuel oil. This is a goal for the experiments, for no one has yet achieved so high a degree of efficiency. To cure out better tobacco and save fuel, Dr. Brown advises growers to insulate their barns and provide means for controlling the ventilation. If these things are done, heat distribution in the barn will be greatly improved. A well-chanked log barn, he points out, is well insulated and is probably as good a barn for its cost as a farmer can build.

In some bright-leaf tobacco areas there is abundant wood usable only as fuel. Many farmers therefore prefer to burn it in tobacco curing barns rather than more expensive fuels. Controlling wood fires, however, requires the full-time attention of responsible workers. Many of the tobacco barn fires which take a high yearly property toll in North Carolina and other parts of the flue-cured tobacco region can be traced to inadequate care in tending heaters. Dr. Brown reports, however, that attention is now being given at the USDA Forest Products Laboratory, at Madison, Wis., to the development of an automatic wood-burning furnace with a thermotatically controlled draft, which would do much to make wood safer and more efficient ar fuel for tobacco barns.

* A new USDA agricultural engineer assigned to the tobacco curing research is James M. Stanley, who comes to the Farm Electrification Division staff from the Virginia Agricultural Extension Service. Stanley is a graduate in agricultural engineering of Virginia Polytechnic Institute, and a junior member of ASAE. He was a captain in the Army, and was stationed in Japan during the winter of 1945-46. After a few months at Oxford, Mr. Stanley will go to Tifton, Ga., for parallel curing investigation in cooperation with the Georgia Coastal Plain Experiment.